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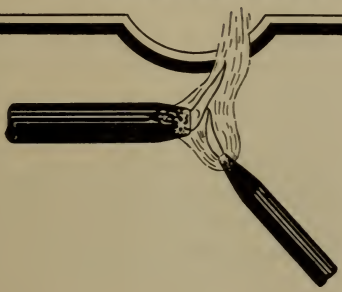
National
PROJECTOR CARBONS



THIRD EDITION

CANADIAN NATIONAL CARBON COMPANY
LIMITED
CARBON SALES DIVISION
TORONTO, ONT., CANADA

Montreal *Winnipeg* *Vancouver*

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Toronto, Ont., Canada

PREFACE

THE carbon arc has the greatest brightness per unit area of any artificial light source known, rivaling that of the sun. It is not surprising, then, that it has been adapted to the projection of motion pictures, to the projection of stereopticon slides, to spot and flood lighting in theatres, to the lighting of studios for the taking of motion pictures, to the lighting of photographer's studios, to photo-engraving, to the large and powerful searchlights used by the Army and Navy, and last, but not least, to the modified type of searchlight used to illuminate the Air Mail Fields being established throughout the country. This book, however, will be largely confined to a discussion of the first mentioned use, that is, the projection of motion pictures.

In addition to being the most powerful source of artificial light, the carbon arc is also the most flexible. The light on the screen can be varied in intensity at the will of the projectionist. For light films the current can be reduced, and for dark or colored films, increased.

The carbon arc is easy to operate. A few rules, however, should be kept in mind. This book has been prepared with the idea of assisting projectionists to obtain the maximum efficiency from their carbons. While the discussion herein will be as comprehensive as possible, it may be that your particular problem of carbon arc projection has not been touched upon. If so, please feel free to write to the Canadian National Carbon Company, Limited, Carbon Sales Division, Toronto, Ont., Canada, or to discuss the matter with one of our representatives.

Toronto Plant of National Carbon Company, Limited

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CHAPTER 1

Carbon

BASIC raw materials are a vital factor in the modern industrial world. This is often called "The Age of Steel," but there are other materials on which the advantages and conveniences of modern life are equally dependent. Rubber, glass, textiles, copper, and many other basic materials can be named as essential to our present mode of life. Among these is carbon, which plays an humble but most important role. Without carbon, the wheels of many industries would cease to turn; the manufacture of aluminum, steel, and many important alloys would be seriously handicapped; the generation of electric power on the present huge scale would be impossible, and our greatest agency for education and entertainment, the motion picture industry, would come to an end.

Carbon is an element which is found in abundance in all parts of the world since it is a constituent of all organic materials. The purest form of carbon is the diamond. Other well known forms of essentially pure carbon are graphite, lampblack, charcoal and coke. The latter forms, however, usually contain some mineral or volatile impurities. Coal contains a very high percentage of carbon as well as a variety of tarry hydrocarbons from which the numerous coal-tar products are derived.

The peculiar physical and chemical characteristics of carbon adapt it to many uses for which no other material is available. It has also been found better adapted to many applications than materials formerly used.

From a chemical standpoint carbon is very inactive, resisting the effects of most acids and other corrosive chemicals. At incandescent temperatures it does not melt and the rate of oxidation is relatively

slow. It may readily be formed in a variety of shapes, either in the initial plastic condition or later by machining in solid form. In graphitic form carbon is valuable as a lubricant. Carbon articles of graphitic composition can be used on many applications where an anti-frictional characteristic is necessary but where, due to temperature or other inhibiting factors, oil or grease lubrication is not feasible. The thermal conductivity of carbon, especially in non-graphitic form, is low as compared with that of most metals. While much higher in electrical resistance than the metals, carbon is a good conductor of electricity, a characteristic which adapts it to many uses in the electrical field. The contact resistance of carbon with other elements of an electrical circuit is much higher than any metal, in which respect it is peculiar to other materials of good electrical conductivity.

The various industrial applications of carbon include carbon brushes, for motors and generators; welding carbon products; carbon anodes and electrodes, used in electro-chemical and electro-metallurgical industries; carbon Raschig rings, carbon tubes and carbon lining, used in handling and processing acids and other corrosive materials; dry cells; and numerous special applications among which may be mentioned switch and circuit breaker contacts, resistance discs, steam turbine packing, thrust rings for automobile clutches, back plates, diaphragms and granular carbon for telephones, electronic tube anodes and grids and, in the form of pure graphite powder, as a lubricant and a constituent of lubricating greases.

The original commercial application of carbon on an extensive scale was in the electric arc lamp. Here the peculiar characteristics of this element make possible a quality and intensity of illumination which cannot be obtained in any other way. Possessing good electrical conductivity but low thermal conduc-

tivity, infusible and slow burning at the extreme temperature of the arc, carbon has proved to be the ideal electrode material for this purpose.

The carbon arc lamp is used for general illumination to a more limited extent than was formerly the case but the development of new types of carbons to meet special applications has extended its use into other fields where it has shown marked superiority over other sources of illumination. In the home — as well as in hospitals and sanatoria, the carbon arc is used to produce artificial sunlight and radiation of specialized character which physicians practicing light therapy have found valuable in the prevention and cure of certain physical disorders. The carbon arc has become an important tool of industry for processing materials by means of photo-chemical reactions and for accelerated tests of materials which tend to deteriorate under the action of sunlight. The most powerful searchlights and aviation field flood lights are highly developed types of carbon arc lamps using carbons designed for this specific purpose. Thousands of carbon arcs are in daily use in photography, photo-engraving, blue printing. and allied industrial processes. The motion picture industry would never have reached and could not maintain its present high plane without the aid of the carbon arc which is used both for studio illumination and for the projection of motion pictures on the screen. The large screen, long throw, and high level of screen illumination in the modern theatre require an intensity in the light source that only the carbon arc can supply — a crater brilliancy sixteen million times the brilliancy of the screen.

The demands made upon projector carbons are extremely severe and the present high quality of National Projector Carbons has only been attained by painstaking research, backed by years of manufacturing experience. Great care is necessary in selecting raw materials of the highest possible purity

and in maintaining close control over every process in the six to eight weeks' period of production.

Projector carbons must conduct electricity at very high current densities ranging from 140 to over 1000 amperes per square inch. At the same time, they must conduct little heat from the arc in order that the maximum possible crater temperatures may be maintained and a minimum amount of heat conducted to the operating mechanism of the lamp. Only carbon can satisfy these conflicting demands. Constant research is necessary to produce new types which will meet or anticipate the demands created by the steady development of the motion picture industry.

CHAPTER II

Manufacture of Projector Carbons

FROM a thoroughly modern plant, devoted exclusively to the manufacture of carbon products, National Projector Carbons go out to all parts of the world. Accuracy and precision mark every step in production, from raw material to finished product.

The raw materials used in the production of projector carbons are the purest commercial forms of carbon, such as lampblack, and the bonding agents, tar and pitch. The tar and pitch are refined and distilled to the required viscosity under conditions which permit very close control. A view of the pitch plant is presented in Figure 1. The lampblack is produced by burning oil or other suitable hydro-carbons

Figure 1
General View of Pitch Plant

in a special furnace, Figure 2, under carefully controlled conditions of temperature and restricted draft. Conditions are chosen which leave unconsumed a large part of the carbon in the fuel and this settles out in the form of soot or lampblack in the large settling chambers through which the products of combustion pass. Careful laboratory tests at this, as at every subsequent stage of production, check the purity and essential physical characteristics of the product to make sure that it is held to the required standards. A portion of the laboratory is shown in Figure 3.

Figure 2
Section of Lampblack Furnace Room

All solid materials used in the manufacture of carbon must first be reduced to a fine powder, usually referred to as flour. In Figure 4 may be seen the crushing and milling equipment by means of which this pulverizing of the carbon is effected. The crude

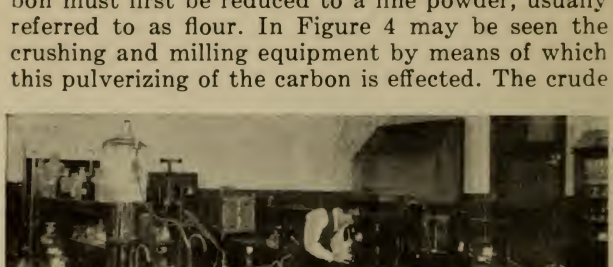


Figure 3
A View of the Laboratory

raw materials pass through these mills and the resulting flour, blended with portions of preceding lots to maintain a maximum degree of uniformity, is stored in bins awaiting the preparation of a carbon mix.

Figure 4
Section of Crushing and Milling Equipment

In preparing a carbon mix the necessary ingredients are accurately weighed and thoroughly mixed with the required proportion of pitch bonding material in heated mixers, such as those illustrated in Figure 5. The resulting mix is a plastic, dough-like

Figure 5
View of Mixing Department

material which is next placed in powerful hydraulic extrusion presses, Figure 6, and forced through accurately calibrated dies in the form of rods of the

required diameter. For carbons that are to be cored these rods are formed with a central opening into which the core material is inserted at a later stage of production. The extruded product is then allowed to

Figure 6
Hydraulic Extrusion Presses

cool. When cool, these "green" carbon rods are fairly rigid but, in reality, are still in plastic form. Before they can be used, they must be baked at a high temperature which converts the pitch bonding agent into coke, leaving a homogeneous solid of pure carbon.

Preparatory to baking, the green carbons are packed in a specially designed, gas fired furnace where they are subjected to a very high temperature. The time-temperature cycle of the baking operation is of great importance and is carefully controlled within close limits throughout the baking period. A typical furnace room is shown in Figure 7.

When the carbons come from the furnace, they are cleaned, cut to the required length, and inspected for straightness and visible faults, after which the core material is forced into those carbons which are manufactured in hollow form. These carbons are again baked to solidify the core material. Next, the carbons

Figure 7
View of Furnace Room

are pointed and those that are oversize are ground to exact diameter. All National Projector Carbons are polished with the exception of High Intensity positive carbons. Since these must be rotated by the feeding mechanism of the high intensity lamp, they are thoroughly cleaned but not polished. After being stamped with the grade designation, each carbon passes through a thorough final inspection which includes x-ray examination of those types containing elements which are made visible by this method of inspection.

Highly specialized equipment is required for the manufacture of projector carbons. At each stage of production, the greatest care is exercised to maintain the conditions which experience has proved essential to uniformity of product. Samples from every lot are tested by burning in the type of lamp for which they are intended. As a result of this extreme care and close technical control, the carbons reaching the user can be depended upon to give uniform quality and intensity of light as well as satisfactory performance in all other respects.

CHAPTER III

The Carbon Arc

IN adapting the carbon arc to its wide field of application, several modifications have been developed both in the carbons and in the lamps in which the carbons are used. The discussion in this chapter will be confined to those types of carbons and lamp equipment used in the projection of motion pictures.

The plain carbon arc, equipped with solid carbons and operating on direct current is the original and simplest type of arc lamp. In the old type, D.C., low intensity projection lamps solid carbons, for reasons later explained, were replaced by neutral cored carbons on the positive and, in some cases, the negative side. The light from the plain, D.C. arc comes almost entirely from the crater of the positive carbon. The arc stream emits relatively little light and the tip of the negative carbon is much less brilliant than that of the positive. This type of arc is illustrated diagrammatically in Figure 8. An actual photograph of the low intensity D.C. arc is reproduced in Figure 9, showing clearly that the positive crater is the source of most of the light. It is evident that this brilliant crater constitutes an excellent source of light for projection purposes.

Figure 8
Plain Carbon Arc — D.C.

With the high current and carbons of large diameter needed to obtain

the required volume of projection light from the old type D.C., low intensity arc, the use of solid carbons would permit the arc stream to shift from point to point over the crater of the positive carbon, producing a flickering light. This tendency is reduced by making the carbons in the form of a thick walled tube with the central opening filled with a softer core of neutral carbon, as shown in Figure 10. The effect of this core is to stabilize the arc stream at the center of the positive carbon tip, producing a light of greater steadiness. Further improvement is effected by substituting a metal coated negative carbon, considerably smaller in diameter

Figure 9
Photograph of Plain Carbon Arc — D.C.

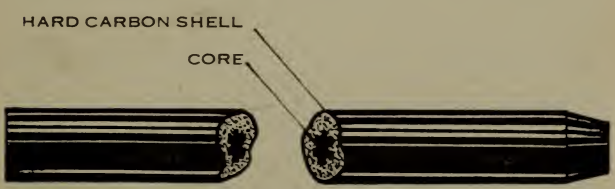


Figure 10

than the positive, for the plain negative carbon originally used, which was equal to or near the diameter of the positive. National Cored Projector and National Orotip Solid or Cored Projector are recom-

mended as positive and negative carbons respectively in old type, low intensity, D.C. lamps. Detailed discussion of their use is given in Chapter IV.

In adapting the carbon arc to alternating current, a different problem is encountered. The reversal in direction of current flow carries the current through a zero point on each reversal with a resulting tendency for interruption of the arc. The introduction of certain rare earth materials into the core of the carbon counteracts this tendency, supporting the arc through the point of zero current and, at the same time, adding color and luminosity to the arc stream itself. Since each carbon is alternately positive and negative, the crater formation is not as distinct on either carbon of the A.C. arc as it is on the positive carbon of the D.C. arc and the temperature of the carbon tips is much lower. For this reason, the crater light from one of the A.C. carbons is less than half of that from the positive carbon of the D.C. arc operated at the same amperage. It has been considered impracticable to focus the craters of both carbons on the aperture plate of the projector. Only the crater of the upper carbon is so focused. However, the combined effect of the crater light from the carbon and the luminescence of the adjacent portion of the flame-like arc stream provides an excellent projection light of snow-white quality.

The brilliant luminescence of the arc stream between White Flame A. C. carbons is clearly seen in Figure 11. The luminescent effect of the core material is quite evident when this illustration is compared with that of the D.C. arc between neutral cored carbons shown in Figure 9. In order to show clearly the character of the A.C. arc stream, the photograph reproduced in Figure 11 was taken with the carbons well separated. In actual projection, however, the lamp is operated with a very short arc, the relative position of the upper and lower carbons being that illustrated in Figure 34, page 39.

National White Flame A.C. Projector Carbon combinations are used in the upper and lower holders of low intensity, A.C. projector lamps. Detailed instructions for the operation of this type of arc are given in Chapter V.

Figure 11
Photograph of A.C. Flame Arc

The influence of current on crater area and arc performance is clearly demonstrated by a series of observations made in the Research Laboratory of National Carbon Company, Inc. These observations were made on a low intensity reflector arc lamp, a modification of the original low intensity D.C. arc, which is described in detail in Chapter VI.

In the lamp used for this test, the positive carbon was held in a horizontal position and the negative at an angle of approximately 75 degrees below the horizontal, as shown in Figure 12. The reflector was removed and the lamp mechanism reversed in the housing so that the positive crater was pointing directly toward the screen. An objective lens was then mounted in such manner that an enlarged image of the crater was projected on the screen. The distance of the crater from both the lens and the screen being kept constant, the diameter of the screen image maintained a fixed ratio to that of the crater, in this test, approximately 30 times the actual diameter. A regular 10 mm x 8 in. National Cored Projector Carbon was used as the positive with a 7 mm x 8 in. National Solid Projector negative. This combi-

nation has an effective current range of 16 to 20 amperes but operates most efficiently at 18 to 20 amperes. However, to fully demonstrate the influence

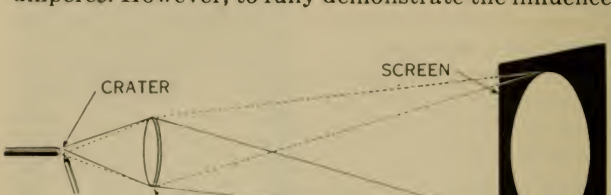


Figure 12
Method of Observing Effect of Current on Crater

of current on crater area and arc performance, the test was started at ten amperes and increased in successive steps of two amperes each to 24 amperes.

It was observed that at ten amperes the light wandered about on the tip of the positive carbon, due to the fact that the tip was too large for the amount of current being employed, with the result that the light was unsteady and required considerable attention to keep it adjusted. As the current was increased, the light became more steady and the white hot tip or crater, increased in size. At 18 to 20 amperes, the point of maximum efficiency, the arc burned quietly and steadily and the white hot spot was about as large as it is possible to obtain with steady burning from the combination of carbons used. As the current was increased above 20 amperes, there was a tendency for the arc to become unsteady, due to the overloading of the combination.

The photographs, Figures 13 to 20, inclusive, show the incandescent craters at the various amperages. They were taken with the camera and lamp in a fixed position, consequently the pictures show the relationship between size of crater and amperage.

The condition of the arc is defined below each picture. *It will be seen that the point of maximum efficiency is just below the maximum current-carrying capacity of the carbons,* or in other words, around 18 to 20 amperes.

The foregoing limitations apply, as has been stated, to regular low intensity carbon trims. The use of National SRA Projector Carbons in the low intensity reflector arc lamp permits operation at higher currents than those recommended for regular, low intensity trims. This subject is discussed in detail in Chapter VII.

The relation of carbon diameter and amperage to quantity and quality of light is of great importance to the projectionist. Although, on a carbon of given diameter, crater area continues to increase with current, there is a point, as indicated in the test just described, beyond which it is not practicable to go. For each diameter and type of carbon there is a relatively narrow range of current within which optimum results are obtained and satisfactory operation will only be secured when the arc current is held within the recommended range. These recommended current values have been determined by careful tests in the theatre as well as in the laboratory. They are presented in subsequent chapters where the operation of the various types of projector lamps is discussed.

Here and there is found a projectionist who uses a trim of larger diameter than recommended in order to save trimming or to cut carbon cost. By so doing he sacrifices quantity, quality and steadiness of light. Compared with other expenses in a theatre, the cost of carbons is negligible — only a few cents a day. The product which the theatre sells to its audience is the picture on the screen. A high-priced film, poorly lighted, loses its effectiveness with resultant loss of patronage. It is sound economy,

Photographs of Incandescent Craters
of D.C., Low Intensity Arc
at 10, 12, 14 and 16 Amperes

Figure 13
Projected Crater Image
10 *Amperes*
Spot small, light unsteady. Very inefficient

Figure 14
Projected Crater Image
12 *Amperes*
Spot somewhat larger, light still unsteady. Very inefficient

Figure 15
Projected Crater Image
14 *Amperes*
Spot larger, light still unsteady

Figure 16
Projected Crater Image
16 *Amperes*
Spot still larger, lower limit for 10 mm Carbons

Photographs of Incandescent Craters
of D.C., Low Intensity Arc
at 18, 20, 22 and 24 Amperes

Figure 17
Projected Crater Image
18 *Amperes*
Good arc. Almost maximum efficiency

Figure 18
Projected Crater Image
20 *Amperes*
Quiet, steady arc. Maximum efficiency

Figure 19
Projected Crater Image
22 *Amperes*
Arc becoming unstable. Carbons overloaded

Figure 20
Projected Crater Image
24 *Amperes*
Arc still more unstable — Frequent hissing. Very inefficient

therefore, to use only the best quality of carbons, in correct combination and operated within the recommended range of current value.

As the motion picture industry developed, increases in the size of theatres, length of throw and dimensions of screen resulted in demands for more and more light from the arc. To meet this need for an enormous volume of projection light, the high intensity arc was developed, using National High Intensity White Flame Projector Carbons.

Low intensity D.C. arcs are operated at current densities of 120 to 165 amperes per square inch in the positive carbon. With SRA carbons, discussed in Chapter VII, current densities up to 205 amperes per square inch are reached. In the high intensity arc, however, current densities of 500 to more than 800 amperes per square inch are attained. This extreme current density requires a highly developed type of carbon of the greatest possible purity and the resulting arc is quite different from that of the low intensity types.

The light from the high intensity arc comes from two distinct sources; the crater of the positive carbon and the tail flame, Figure 21. The light from the tail flame represents about 30 per cent of the total light emitted from the arc but, since it cannot be focused within the dimensions of the aperture plate and any appreciable portion of it utilized by the optical system, the projectionist is interested only in the crater light. The whiteness and intrinsic brilliancy of this crater light exceeds that of incandescent carbon volatilized at atmospheric pressure. It evidently has its source in something more than the solid tip of incandescent carbon. This intensified light can be conceived as coming from a portion of the luminous gases of the tail flame, compressed in the crater of the positive carbon by the negative arc stream and thus augmenting the light from the incandescent carbon tip. This explanation may not accord with

physical fact, but it aids the imagination in visualizing a reason for the remarkably high intrinsic brilliancy of the high intensity carbon arc as compared

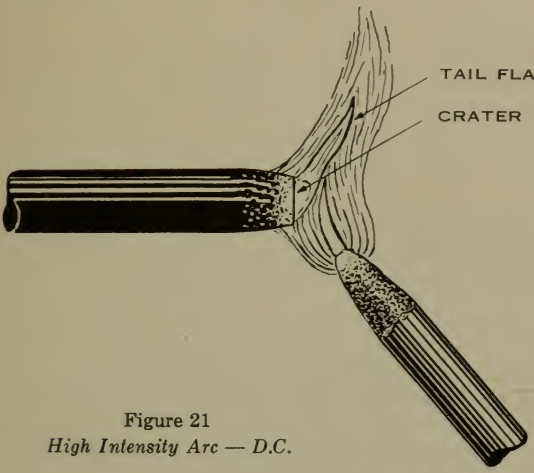


Figure 21
High Intensity Arc — D.C.

with other artificial sources of illumination. The fact that the quantity and quality of light from the high intensity arc, operated at a given current, varies greatly with the manner in which the arc stream from the negative carbon impinges upon the flame of the positive, indicates that some condition obtains which is in a measure equivalent to that described. Instructions for adjusting the high intensity arc so as to obtain best results are given in Chapter VIII.

The large high intensity projection lamps, developed to meet the needs of the larger theatres, cannot be used with economy in theatres of small and intermediate size. There is evident need, however, in theatres of the latter class, for a projection light of better quality, higher intrinsic brilliancy and greater volume than the low intensity D.C. arc is capable of providing. To meet this need, the principle

of the high intensity arc has been extended to arcs of lower power demand which bridge the wide gap between the low intensity D.C. arc and the high intensity D.C. arcs previously available. These later high intensity arcs use smaller diameter, copper coated carbons, can be operated in lamps of simpler construction, and have been adapted to A.C. as well as D.C. operation. The A.C. high intensity arc is discussed in detail in Chapter IX, and the Suprex type D.C. high intensity arc is described in Chapter X.

An interesting comparison is afforded by the following table which shows the intrinsic brilliancy of a number of well-known light sources.

TABLE I

Intrinsic Brilliancy of Light Sources

Light Source	*Candle Power Per Sq. MM.*	*Source of Data*
Tungsten Filament of Incandescent Lamps		International
40 Watt, clear bulb, vacuum type	2.06	Critical Tables
900 Watt, clear bulb, gas filled special	26.6	Critical Tables
Magnetite Arc Stream	6.2	Mott
Flame Arc Stream	8	Mott
Positive Crater of Cored, D.C. Low Intensity Carbon Arc	155-175	Journal of Society of M. P. Engineers
Crater of A.C. High Intensity Carbon Arc	280	Journal of Society of M. P. Engineers
Positive Crater of Non-Rotating, D.C. High Intensity Carbon Arc	380	Journal of Society of M. P. Engineers
Positive Crater of Rotating, D.C. High Intensity, White Flame Carbon Arc	400-800	Journal of Society of M. P. Engineers
Sun at Zenith	920-950	

In the projection of motion pictures it is highly desirable that all portions of the screen be equally illuminated. To accomplish this an evenly distributed field of light must pass through the aperture plate onto the adjacent film. The crater of the carbon arc, practically uniform in intrinsic brilliancy and providing a large volume of light within a small area and practically within one plane, is readily focused on the aperture plate in a beam of uniform intensity. No other source of light compares with the carbon arc in its adaptability to the problems of projection. Its flexibility permits the light to be increased by increase of current when dark or colored films are being shown and decreased by lowering the current when less illumination is required. In electrical efficiency the carbon arc likewise stands supreme. It already occupies the field of theatre projection to the practical exclusion of all other light sources and recently developed projection lamps of low amperage, and simplified operation promise to extend the use of the carbon arc into school rooms, lecture halls, and small auditoriums for which the smallest arc lamps heretofore available provide a much greater volume of light than is required.

CHAPTER IV

Direct Current, Old Type Low Intensity Lamps

THE old type, direct current, low intensity, carbon arc lamp was the first type of lamp used in motion picture projection. The positive carbon is mounted above the negative and slightly inclined from the vertical position so as to expose the crater and permit a greater proportion of the crater light to be picked up by the condenser lens. In one style of lamp, both positive and negative carbons are inclined 20 degrees from the vertical, as shown in Figure 22. In another style, the positive carbon is inclined 15 degrees from the vertical and the negative 10 degrees, as in Figure 23.

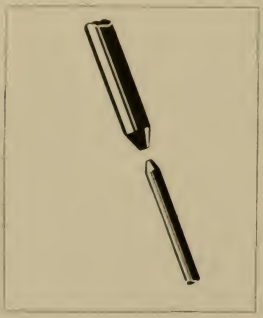


Figure 22

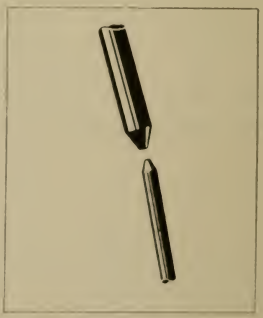


Figure 23

The optical principle of the old type, D.C. low intensity projection lamps is illustrated diagrammatically in Figure 24. In this lamp, as indicated by the illustration, a cone of illumination approximately 45 degrees in angular diameter is picked up by the condenser lens and focused on the aperture plate.

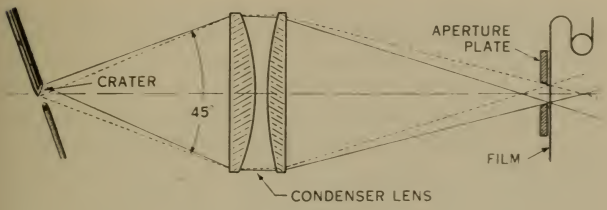


Figure 24
Diagram of Old Type, Low Intensity, D.C. Projection Lamp

As pointed out in Chapter III, the positive carbon used in this type of lamp is always cored, that is, the center of the carbon is filled with a softer mix of carbon known as the core. While the brilliancy of that portion of the crater occupied by the core is a little lower than that of the surrounding solid carbon, this slight disadvantage is more than offset by the greater steadiness given to the arc. In fact, it would be impossible to produce a light of sufficient steadiness for satisfactory projection with solid positive carbons.

Since all of the light that is useful for projection in this type of lamp comes from the crater of the positive carbon, it is essential that the adjustment of the carbons, as they are consumed, be such as to maintain the positive crater in a fixed position where it can be accurately focused on the aperture plate. Likewise, it is essential that the arc stream should not wander from point to point, but should impinge upon the positive carbon in a steady position.

Prior to the advent of National Projector Carbons it was common practice to use a large diameter regular solid or cored projector carbon in the lower or negative holder. In some cases, a negative carbon slightly smaller in diameter than the positive carbon was used, whereas in others, the negative carbon was the same diameter as the positive. With the negative

carbon equal to or near the diameter of the positive, it is impossible to hold the arc steadily on one spot. This results in a changing intensity of light on the screen. To overcome this condition, some projectionists shortened the arc to such an extent that the negative carbon obstructed some of the light from the positive crater. Obviously, another means of correcting this condition was necessary. It was found that the application of a metal coating to the negative carbon (increasing the current carrying capacity so that a $\frac{5}{16}$-inch diameter negative, for example, would carry the same current previously requiring the use of $\frac{9}{16}$-inch diameter plain carbon) imparted the desired steadiness to the arc.

The Silvertip Negative Carbon, introduced to the industry a number of years ago by National Carbon Company, Inc., was the first metal-coated negative carbon placed on the market. This was later superseded by the Orotip Negative Carbon. The Orotip differs in every respect from negative carbons previously manufactured; new shell, new core, new coating. The composition of the shell is such that it burns longer than any other metal-coated negative carbon on the market. The structure of the core is such that, even under the most severe operating conditions, it will not recess or burn back but maintains a quiet and steady arc. The introduction of metal-coated negative carbons brought about a decided change in motion picture projection. In a short time they were adopted by the majority of theatres operating on direct current.

It is evident from the foregoing discussion that best results can be obtained only when carbons are used in proper combination, that is, with the respective diameters of positive and negative carbons in proper relation to each other, and to the current at which the lamp is to be operated. It is clearly shown in Chapter III that imperfect projection is certain to result when carbons are operated

at values of arc current outside of the recommended range and that, for best results, they should be operated near the upper limit of this range. Table II shows the correct combinations of carbons for operation in old type, direct current, low intensity lamps within the specified ranges of arc current:

TABLE II

National Cored and Orotip Projector Combinations
For Old Type, Low Intensity Lamps

Arc Amp.	*Approx. Arc Volts*	*Polarity*	*Size Inches*	*Kind*
25- 50	51-56	Positive	$\frac{5}{8}$ x 12	National Cored Projector
		Negative	$\frac{5}{16}$ x 6	National Orotip Solid or Cored Projector
50- 65	56-59	Positive	$\frac{3}{4}$ x 12	National Cored Projector
		Negative	$\frac{1}{2}$ x 6	National Orotip Solid or Cored Projector
65- 70	59-60	Positive	$\frac{7}{8}$ x 12	National Cored Projector
		Negative	$\frac{1}{2}$ x 6	National Orotip Solid or Cored Projector
70- 85	60-63	Positive	$\frac{7}{8}$ x 12	National Cored Projector
		Negative	$\frac{3}{8}$ x 6	National Orotip Solid or Cored Projector
85-120	63-68	Positive	1 x 12	National Cored Projector
		Negative	$\frac{7}{16}$ x 6	National Orotip Cored Projector
120-140	68-70	Positive	$1\frac{1}{8}$ x 12	National Cored Projector
		Negative	$\frac{1}{2}$ x 6	National Orotip Cored Projector

A very large percentage of complaints registered are found, on investigation, to be due to operating conditions, to carbons being used in the wrong combination, to operation outside of the recommended current range or to incorrect position or improper alignment of carbons, rather than to inferior quality of the carbons themselves. It will be of value to the projectionist to consider the causes of some of the more common complaints.

Arc Traveling or Wandering

As has already been stated, before the advent of metal-coated negative carbons the common practice was to use large diameter regular solid or cored projector carbons in the lower holder. This negative carbon in most cases was slightly smaller in diameter than the positive, although in others, the same diameter was used. With the large blunt point on the negative, it was not possible to keep the arc steady and in one spot — see Figure 25 showing a ¾-inch cored upper operated with a ⅝-inch lower.

Figure 25

This combination resulted in an unsteady light on the screen. When operated with a short arc to reduce traveling and make a steadier light, the large negative carbon in some instances masked or obstructed some of the light from the positive crater and this naturally decreased illumination. Obviously the thing to do was to use a negative of smaller diameter. A plain carbon would not carry the current so a metal coating was applied and the Orotip Carbon of today is the result.

While the majority of theatres in this country using the type of lamp discussed in this chapter now burn Orotip negative carbons, there are still some theatres using the old style combinations with large diameter, uncoated negatives. For best results, the use of Orotip negative carbons is strongly recommended. Such a trim is illustrated in Figure 26.

Figure 26

Lip on the Upper Carbon

Figure 27
Negative set too far forward

Figure 28
Negative set too far back

Figure 29
Correct form of positive crater

A "lip" on the upper carbon is caused by improper setting of the carbons. Figure 27 shows a side view of the lip formed on the positive by setting the negative carbon too far forward. Figure 28 shows, from the front, the blunt point obtained when the negative carbon is set too far back. Obviously, most of the light in this case will be thrown downward rather than forward through the condensing lens. Figure 29 shows a good crater formation obtained with the negative carbon in the proper position. This crater throws most of the light forward toward the condensing lens.

Mushroom Points

Figure 30

If too short an arc is drawn a "button" or "mushroom tip" is formed on the negative carbon (See Figure 30). This condition is caused by the deposition of particles of carbon from the positive on to the tip of the negative carbon, and will occur with any style or make of negative carbon when the arc is kept too short. This condition is sometimes spoken of as "freezing of the arc." The proper arc length is about ¼-inch to ½-inch on this type of lamp. When striking the arc, the points should be separated quickly, otherwise the positive crater may be shattered or both points graphitized.

Excessive Spindling

One cause of excessive spindling is overloading the carbons. Figures 31 and 32 show respectively a ⅝-inch cored positive carbon and a $\frac{5}{16}$-inch Orotip solid negative carbon which have been operated above their rated current capacity. Care should be taken to use the combination of carbons shown in Table II on page 31 and to keep within the range of current recommended for each combination.

Spindling may also result from poor contact in either the positive or negative carbon holder. The jaws of both upper and lower carbon holders should be cleaned regularly so that contact with the carbons will be smooth and firm.

Sputtering at the Arc

Figure 31

Figure 32

Sputtering at the arc may result from the carbons not being set in the proper position or from operation with too short an arc. A more frequent cause of sputtering, however, is damp carbons. Carbons are porous and tend to absorb any excess of moisture. They are baked at extremely high temperatures in the factory and, when shipped, are thoroughly dry. In shipment, however, they may be exposed to damp weather or, at the destination, stored in a damp location. Under these conditions, they will absorb sufficient dampness to affect their operation. Carbons should always be kept in a dry place. A great many projectionists have formed the habit of laying a few carbons on top of a rheostat in order to expel any moisture that might have been absorbed after leaving the factory. Others put a trim in the lamp house before burning. Either practice is a good one and is to be recommended since dampness may cause a carbon to chip at the crater as well as sputter at the arc.

It should be added here that carbons are not perishable. They are as good ten years after leaving the factory as on the day of shipment. If they have absorbed only water they can be dried out in any suitable manner without their operation being impaired. However, if a chemical has been spilled on them, they may be rendered worthless, depending upon the nature of the chemical.

CHAPTER V

Alternating Current, Low Intensity Lamps

FROM the discussion of several types of carbon arcs in Chapter III, it is evident that, in many ways, direct current possesses definite advantages over alternating current as a source of power for projection. The principal reason for this is that the direct current arc affords, in the crater of the positive carbon, a brilliant source of light, approaching pure white in color, easily focused on the aperture plate and representing a large proportion of the total light emitted from the arc. The alternating current arc between neutral cored carbons, on the other hand, affords less than half as much usable light as the D.C. arc of equal electrical input, and the color is more yellow, due to the lower temperature of the carbon tips.

Direct current is available in the down town section of most cities, but the electrical distribution to outlying theatres is usually A.C. In these cases, direct current is supplied to the projection lamps by means of motor-generator sets, small converters, or some type of rectifier. There are cases, however, where it is not practicable or economical to use any of these methods of converting alternating to direct current and the resulting need for an efficient alternating current arc led to the development of National White Flame A.C. Projector Carbons. As previously described, an arc supporting material has been added to the core of these carbons producing a flame-like arc stream of pure white color. The condensing lens of the A.C. projector lamp focuses on the aperture plate some of the light from this luminescent arc streams as well as the light from the incandescent tip of one of the carbons. An efficient projection light

of excellent color quality is thus provided from an alternating current circuit.

The arc supporting material in the core of National White Flame Projector Carbons possesses another desirable quality. It practically eliminates the noise which is characteristic of the A.C. arc between neutral cored carbons.

In some A.C. projection lamps the positions of both upper and lower carbons is fixed. Where adjustment is possible it is recommended that the upper carbon be set at an angle of 20 degrees from the vertical and the lower in a vertical position as shown in Figure 33.

Figure 33

A.C. projector carbons are usually sold in sets consisting of one 12-inch upper and two 6-inch lowers, both upper and lower carbons being cored and of the same diameter. Separate uppers or lowers may be purchased, however, to take care of cases where the sets do not burn out evenly. The recommended arc

current and voltage for the various combinations available are given in the table below:

TABLE III

National White Flame A.C. Projector Carbon Combinations

Arc Amperage	*Arc Voltage*	*Upper Carbon*	*Lower Carbon*
25-40	25-28	½"x12"	½"x6"
40-60	28-32	⅝"x12"	⅝"x6"
60-75	32-35	¾"x12"	¾"x6"
75-100	35-40	⅞"x12"	⅞"x6"

The difficulties encountered in the operation of low intensity, A.C. projection lamps are, in general, similar to those discussed in the preceding chapter on low intensity, D.C. lamps and the remedies are of like character. A few other suggestions, peculiar to the A.C. arc, may be pertinent.

In all cases White Flame, cored carbons of the same diameter should be used in both holders of the lamp.

Unless the position of the carbons is watched closely the lower carbon may mask a portion of the crater of the upper carbon, preventing the full amount of light reaching the condenser. After each reel, it is well to lengthen the arc to burn off the lip which has formed on the carbon tip and maintain the proper V-shaped gap between the craters of upper and lower carbons.

The arc length on A.C. should be much shorter than on D.C. to secure steady burning. From $\frac{1}{16}$-inch to $\frac{1}{8}$-inch at the nearest point is a suitable arc

Figure 34
Correct Adjustment of A.C. Trim

length. Figure 34 shows an A.C. carbon trim adjusted in a manner to give the maximum light for projection.

CHAPTER VI

Direct Current, Low Intensity Reflector Arc

THE development of the direct current reflector carbon arc lamp, operating at currents from 10 to 42 amperes, represents such a striking improvement in efficiency over the old type, low intensity direct current lamps that it has largely replaced them in motion picture theatres.

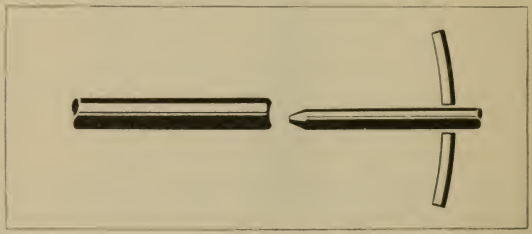


Figure 35

There are two general types of low intensity reflector lamps; one with both positive and negative carbons held in a horizontal position as in Figure 35.

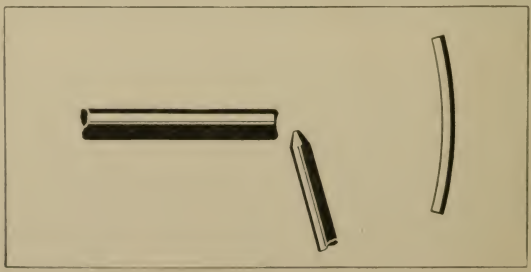


Figure 36

This is the type used in this country. In the other type, the positive carbon is set in a horizontal posi-

tion and the negative at an angle of 75 degrees from the horizontal, as shown in Figure 36. The latter type is quite popular abroad.

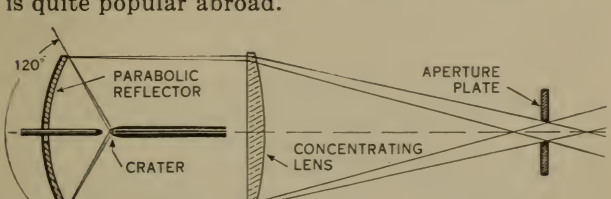


Figure 37
Low Intensity, D.C. Reflector Arc Lamp with Parabolic Mirror

In both of these types, the positive carbons face a mirror against which the light is thrown and reflected toward the aperture plate. Two types of mirrors are commonly used, parabolic and elliptical. The parabolic mirror has the property of reflecting in parallel rays the light from a point source placed at its focus. This type of mirror is used with a concentrating lens to focus this parallel beam of light at the aperture plate as illustrated in Figure 37.

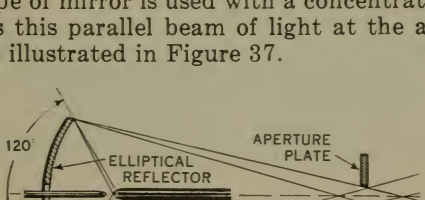


Figure 38
Low Intensity, D.C. Reflector Arc Lamp with Elliptical Mirror

The elliptical mirror is self-focusing. In mathematical language, the ellipse is a curve having two foci. In practice, this means that a point source of

light placed at one focus of an elliptical reflector will be reflected through the other focus from any point on the reflector. When the elliptical reflector is used, there is consequently no need for a concentrating lens. Figure 38 illustrates this type.

The advantage of the reflector type of lamp lies in the wide angle of the cone of illumination which it picks up from the arc. As indicated in Figures 37 and 38, this angle is 120 degrees. This makes it possible to project on to the screen several times the amount of light available from an arc crater of the same intensity in the old type low intensity lamp where it was only possible to pick up, by means of the condenser lens, a cone of illumination of about 45 degrees angular diameter. See Figure 24, in Chapter IV.

The positive carbon used in the regular low intensity reflector arc lamp trim is slightly larger in diameter than the negative, and should burn with a cup-shaped crater as shown in Figure 39. In the type of

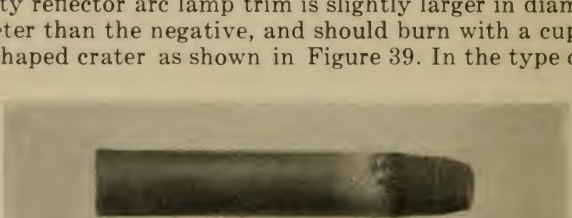


Figure 39

lamp having a horizontal trim, this cup-shaped crater is obtained by setting the negative carbon slightly lower than the positive, as indicated in Figure 35. In the type of lamp having the angular trim, it is obtained by adjusting the height of the negative tip so that the crater will be formed as nearly as possible in a vertical plane, without the negative carbon being raised high enough to obstruct the light from the crater.

The correct combinations of regular positive and negative carbons for use in direct current reflector lamps are given in the following table, together with the range of current recommended for each combination:

TABLE IV

National Cored and Solid Projector Combinations for D.C. Mirror or Reflector Arc Lamps Horizontal Trim Lamps

Arc Amp.	*Approx. Arc Volts*	*Polarity*	*Size and Kind*	
			National Cored Projector	*National Solid Projector*
10-15	54-57	Positive	9 mm x 8″	
		Negative		6.4 mm x 8″
16-20	54-57	Positive	10 mm x 8″	
		Negative		7 mm x 8″
21-25	54-57	Positive	12 mm x 8″	
		Negative	8 mm x 8″	or 8 mm x 8″
26-30	54-57	Positive	13 mm x 8″	
		Negative	9 mm x 8″	
31-35	54-57	Positive	14 mm x 8″	
		Negative	10 mm x 8″	

National Cored and Solid Projector Combinations for D.C. Mirror or Reflector Arc Lamps Angular Trim Lamps

Arc Amp.	*Polarity*	*Size*	*Kind*
6-10	Positive	9 mm x 8″	National Cored Projector
	Negative	8 mm x 8″	National Cored Projector
11-15	Positive	10 mm x 8″	National Cored Projector
	Negative	9 mm x 8″	National Cored Projector
16-20	Positive	12 mm x 8″	National Cored Projector
	Negative	10 mm x 8″	National Cored Projector

In operating the reflector arc lamp the same care is necessary to maintain clean and firm contacts on

the carbon, clean reflector, and correct position of carbons that is required in other types of lamps.

It has already been stated that, with the horizontal trim, the negative should be set slightly below the center of the positive carbon so as to obtain a well-formed crater in the vertical plane as illustrated in Figure 39. If the negative carbon is set too low, a lip will be formed on the upper edge of the positive car-

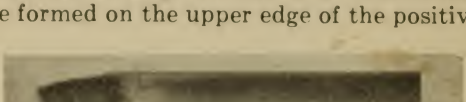


Figure 40

bon as in Figure 40, and a portion of the light will be thrown downward so that its value for screen illumination is lost. If the negative is set too high, a lip

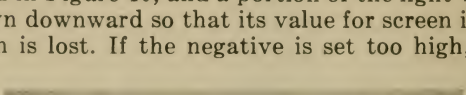


Figure 41

will be formed on the lower edge of the positive carbon, Figure 41, and some of the light thrown upward and lost.

The setting of carbons in the type of reflector lamp with angular trim should likewise be such as to avoid distortion of the crater form. It is not feasible to define in exact dimensions the relative positions of positive and negative carbons in either type of lamp, but observation of the crater formed will enable the projectionist to determine the position giving the best results. It will be realized, of course, that in either type of lamp, the positive and negative carbons must be in alignment in a lateral direction or some of the light will be deflected to the side.

Operation of carbons beyond their rated capacity results in spindling, especially on the negative carbon. Figure 42 shows a 12 mm. x 8-inch National

Figure 42

Cored Positive and an 8 mm. x 8-inch National Solid Negative burned at 40 amperes, the maximum recommended current for this size trim being 25 amperes. It will be noted that both positive and negative carbons have spindled as a result of this heavy over-load, the latter to an excessive degree. The same trim is shown in Figure 43, operated at the specified current.

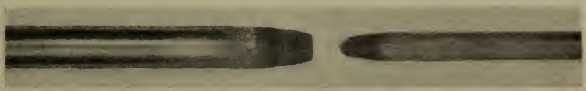


Figure 43

Excessive spindling may also be caused by corroded contacts, lack of firm pressure on the carbons in the holder, or by the carbons being clamped too far from the tips, thus creating excessive heat from the arc current being carried through too great a length of exposed carbon.

The reflector arc lamp is sensitive to draughts of air within the lamp housing. This is due to the fact that the current employed is considerably less than that in other types of lamps and the arc stream consequently more easily disturbed. The ventilating system on the lamp should be so regulated that, with the exhaust fan in operation, the arc will not be extinguished.

In addition to maintaining a crater of proper form on the positive carbon, it is essential that this crater be kept at the focus of the reflector. Reflector arc lamps equipped with a motor driven carbon feeding mechanism should be adjusted to feed both positive and negative carbons at their normal rate of consumption, thus maintaining the positive carbon crater in a fixed position with an arc gap of uniform length. To make this possible, the rate of feed of the negative carbon is made adjustable relative to that of the positive. Every lamp is equipped with an indicator showing the correct position for the positive crater at the focus of the mirror. If allowed to deviate from this position to any great extent, the effective illumination will be reduced.

Proper adjustment of carbons in the low intensity reflector arc lamp is a matter of great importance which is discussed in more detail in the succeeding chapter on SRA Carbons. The arc currents permissible with SRA carbons are considerably higher than those recommended for the regular low intensity reflector arc trims. The basic principles of operation, however, are common to both types of carbons.

CHAPTER VII

SRA Projector Carbons*

IN the last few years the need for more light even in the smaller theatres has been augmented by various factors such as the use of perforated sound screens, colored films, and the demand for a higher level of general illumination. Carbon manufacturers have endeavored to aid the situation in the smaller theatres by developing low intensity reflecting arc carbons which carry higher currents than those previously available. National SRA Projector Carbons are the result of these efforts on the part of the research staff of National Carbon Company, Inc.

The improvements embodied in National SRA Projector Carbons make possible a steady arc at higher currents than are permissible with regular low intensity carbons. The current limitations of the latter, discussed on pages 19 to 24, have been overcome in the SRA Carbons. The higher intrinsic brilliancy thereby made available when National SRA Carbons are used in low intensity, direct current, reflector arc lamps, affords substantial increase in screen illumination.

The recommended range of current for the SRA combinations in common use is as follows:

28 to 32 amperes:

Positive, 12 mm x 8 in. National SRA Cored Projector.

Negative, 8 mm x 8 in. National SRA Cored Projector.

32 to 42 amperes:

Positive, 13 mm x 8 in. National SRA Cored Projector.

Negative, 8 mm x 8 in. National SRA Cored Projector.

*This chapter includes a resume of a recent paper presented before the S.M.P.E.

For reasons that will be explained in the subsequent text of this chapter, these sizes cover the present practicable operating range of arc current. To what degree these limits may be extended by future developments in carbon manufacture cannot be foretold.

It is believed that data on the characteristics of the present SRA Carbons and their application to projection problems may suggest ways to improve still further the illumination of the screen. Accordingly, the results of a series of laboratory tests are here presented. Data on 10 mm and 14 mm carbons have been included although production, as previously stated, is confined to the 12 mm and 13 mm sizes for which there is active demand.

The current carrying capacities of these carbons are given in Table V. Approximately two amperes have been allowed as a factor of safety between the maximum recommended current and the extreme upper limit of the carbons.

TABLE V

Current Ratings of SRA Positive Carbons

Carbon Diameter	*Minimum Recommended Current*	*Maximum Recommended Current*	*Current Above Which There is Constant Sputtering*
10 mm	21	24	25
12 mm	28	32	34
13 mm	32	42	44
14 mm	42	52	55

If the carbons are burned above their maximum current, the light will be unsteady and there will be no appreciable gain in candle-power on the screen. If the carbons are burned below the minimum current the efficiency of light production is decreased and the arc tends to become unsteady because the crater

area is too small to sufficiently cover the end of the carbon.

It is the light from the crater of the positive carbon which is of value. The light from the negative carbon and arc stream is only approximately 10 per cent of the total light and cannot be utilized for projection purposes. The diameter of the positive crater increases with increasing current. The data in Table VI illustrate the change for these particular carbons.

TABLE VI

(*See Figure* 48)

Change in Crater Diameter with Current
SRA Positive Carbons

Carbon Diameter	*Current*	*Crater Diameter in Inches*	*Crater Area*	
			Sq. In.	*Sq. MM.*
10 mm	21	.262	.0539	34.8
10 mm	24	.278	.0607	39.2
12 mm	28	.311	.0760	49.0
12 mm	31	.325	.0830	53.5
12 mm	34	.344	.0929	60.0
13 mm	34	.347	.0946	61.0
13 mm	40	.378	.1122	72.4
13 mm	44	.392	.1207	77.9
14 mm	44	.404	.1282	82.7
14 mm	50	.419	.1379	89.0
14 mm	55	.432	.1466	94.6

The action of the direct current on the crater of the positive carbon heats it to approximately 4,000 degrees K., the vaporizing temperature of carbon. This gives the crater an intrinsic brilliancy of 130 to 175 candles per square millimeter, which is exceeded only by the crater of a high intensity carbon.

As shown in Figure 44, the intrinsic brilliancy is uniform on the core, rises sharply to a maximum on the shell just outside the core, and decreases again

near the edge of the crater. If the carbon were solid instead of cored, there would be no dip in the intrinsic brilliancy at the center of the crater. How-

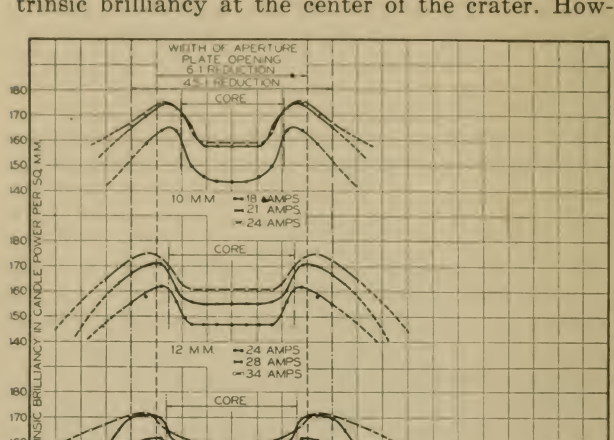


Figure 44

ever, the core is necessary to furnish arc-supporting materials and to maintain the crater position constant with respect to the carbon. Without it, the current would have to be reduced materially and the crater would travel around the end of the carbon and would result in a very unsteady light on the screen.

It should be noted that above a certain current for each size carbon there is practically no increase in intrinsic brilliancy of the central part of the crater — merely an increase in crater size and in intrinsic brilliancy near the edges of the crater. It is also evident that after this critical current has been reached, the intrinsic brilliancy is the same for the central portion

of the crater on a 10 mm carbon as for the 13 mm carbon. This important characteristic will be referred to later in relation to the optical system. The approximate current at which the central portion of the

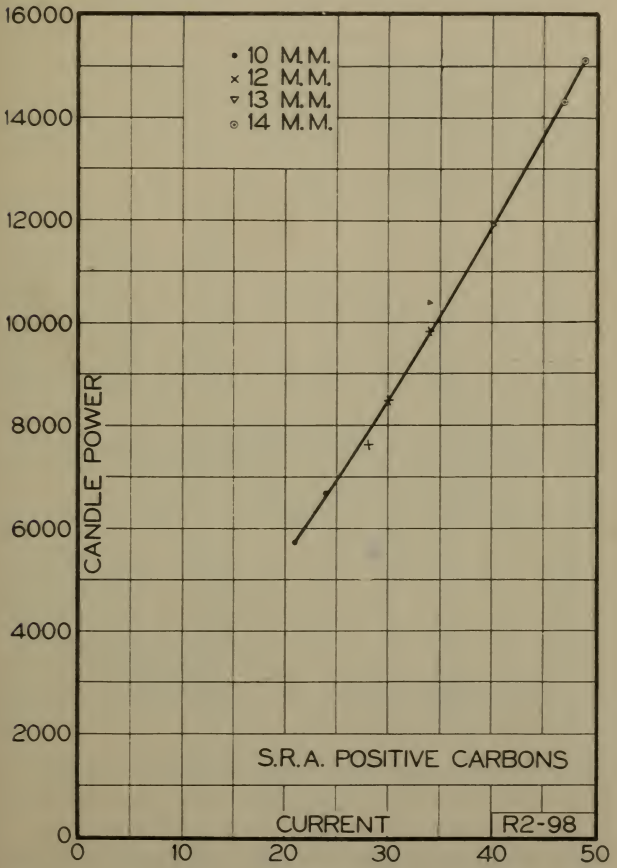


Figure 45

Variation of Candle Power of Crater with Current

crater approaches its maximum is the minimum recommended current in Table V. At lower amperage the intrinsic brilliancy falls off rapidly.

The candle-power of the crater from a point directly in front is shown in Figure 45 for various values of arc current. Of more importance for projection than the candle-power directly in front of the crater is the light distribution about the crater. Polar candle-power curves for two currents are given in Figure 46. The polar curves for other currents and carbon

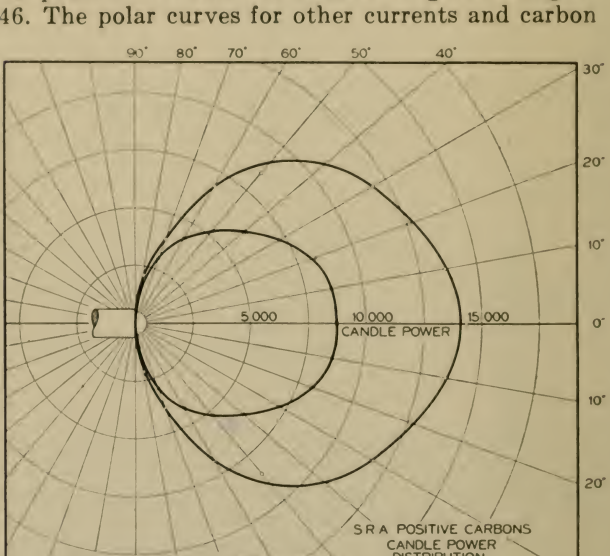


Figure 46

sizes would be similar in shape and proportional to the candle-power values in Figure 45. These polar curves are misleading if they are not carefully

analyzed. A better method of expressing the same thing is to compute the quantity of light in each angular sector. These values as well as the total quantity of light and the cumulative percentages are given in Table VII.

TABLE VII

Angular Light Distribution, SRA Positive Carbons

Angle	*Aver. Cp.*	*Lumens Light Flux in Various Zones*	*Per Cent of Total Lumens*	*Cumul've Per Cent of Tot. Lum's*
12 Millimeter Carbons at 30 Amperes				
0-10	8,695	825	3	3
10-20	8,360	2,360	9	12
20-30	7,590	3,520	13	25
30-40	6,670	4,180	16	41
40-50	5,730	4,430	17	58
50-60	4,730	4,230	16	74
60-70	3,600	3,570	14	88
70-80	2,220	2,260	9	97
80-90	720	780	3	100
		26,155 (Total Lumens)		
14 Millimeter Carbons at 47 Amperes				
0-10	13,950	1,320	3	3
10-20	13,100	3,700	9	12
20-30	12,200	5,600	14	26
30-40	11,350	7,130	17	43
40-50	9,650	7,460	18	61
50-60	7,630	6,850	16	77
60-70	5,340	5,300	13	90
70-80	2,930	3,100	7	97
80-90	1,015	1,110	3	100
		41,570 (Total Lumens)		

The optical systems used in the present low intensity reflecting arc lamps have been described in the preceding chapter. Briefly, the systems commonly employed use a parabolic reflector with a con-

densing lens or an elliptical reflector alone. Irrespective of the system used, the light pick-up from the arc has usually been a cone of 120-degree opening which, according to Table VII, would include approximately 75 per cent of the light from the positive crater. The light gathered by the reflector is focused on the aperture plate in the form (neglecting spherical aberration) of an image of the crater. The magnification of the system is approximately six to one. Under these conditions it is *theoretically* correct that the maximum volume of light on the screen is obtained when a current of 21 amperes is used on a 10 mm carbon and that higher currents merely give more light in that portion of the crater image which is absorbed by or reflected from the aperture plate. It can be seen that this is plausible by a reconsideration of Figure 44. In this figure, instead of projecting the crater face onto the aperture plate, the width of the aperture plate opening with the proper reduction for a six to one magnification has been projected back onto the crater. The values of intrinsic brilliancy for the portions of the craters within the aperture plate width indicate that no more light could be expected to go through the aperture plate from a 13 mm carbon at 44 amperes than from a 10 mm carbon at 21 amperes. They also show that if the carbon is run below its rating, for example, 31 amperes on a 13 mm carbon or 24 amperes on a 12 mm carbon, there will be less light through the aperture plate opening because of the lower intrinsic brilliancy of the middle portion of the crater.

However, there are very important reasons for not using, for ordinary theatre projection, the smallest size carbons or the lowest current theoretically possible. The total light and the uniformity of the light on the screen depend largely on the position of the positive crater with respect to the focal point of the mirror. In practical projection it is very difficult to hold the positive crater within 0.025 inch of the cor-

rect focal point. This accuracy would be necessary to obtain the maximum screen light from a 10 mm carbon at 21 amperes with a mirror arc system in common use. The 12 mm carbon, however, has suf-

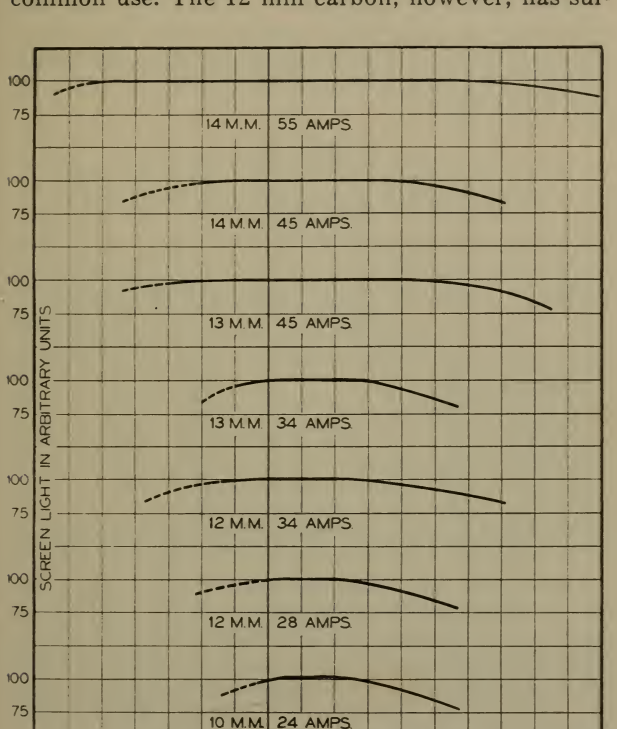


Figure 47

ficient amplitude of position to make operation easy and is, consequently, the smallest size for which there is active demand.

The change in the light on the screen with the movement of the positive carbon along the axis of the reflector of a typical optical system for various currents and sizes of carbons is shown in Figure 47 and Table VIII.

TABLE VIII

SRA Positive Carbons Extent of Movement of Positive Crater Along Axis Without Materially Decreasing Screen Light

Carbon Diam.	*Current*	*Total Allowable Movement in Inches Along Axis for a Change of No More Than 5 Per Cent in Screen Illumination*
10 mm	21	.06
10 mm	24	.10
12 mm	28	.10
12 mm	34	.15
13 mm	34	.11
13 mm	45	.21
14 mm	45	.18
14 mm	55	.34

From these considerations, the use of a 13 mm carbon at 40 amperes appears to be amply justified to guarantee uniformity of screen illumination. Even with this carbon and current, the positive crater must be held within 0.07 inch of the focal point of the reflector to maintain the screen illumination within 5 per cent of the possible maximum.

The permissible movement of the crater away from the axis for the various carbon sizes and currents without a material decrease in the screen light may be determined from Figure 48 and Figure 44, where the aperture plate opening for a six to one magnification is compared with the crater diameters and intrinsic brilliancies. These data show the advantage

of using a carbon at or near its maximum current capacity rather than the next larger size carbon below, or even near, its minimum rated current. They also show that the 13 mm carbon affords ample

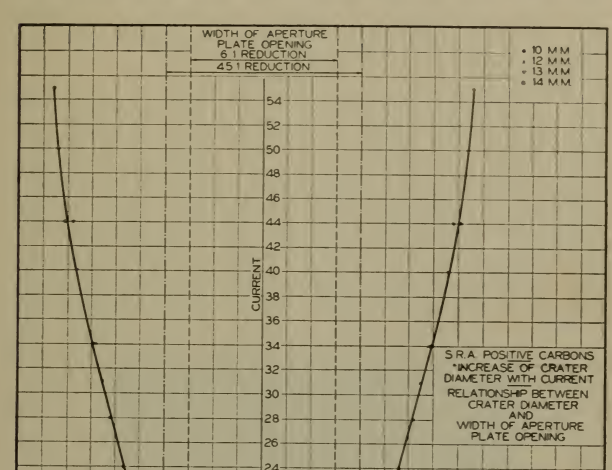


Figure 48
See Table VI

latitude for operation with the optical systems commonly used and that a carbon of larger diameter is not required.

The limitations of the low intensity mirror arc optical systems heretofore available have been clearly defined. The fastest projection lens would pass a cone of light only approximately 20 degrees in total angular diameter. This practically fixed the magnification ratio of the reflector system at six to one and the angle of light taken by the reflector from the crater at 120 degrees. If the angle of the reflector

were increased to take a greater angle of light from the crater, or if the magnification were reduced, there would be no advantage because, in either case, the angle of divergence beyond the aperture plate would be increased and the projection lens could pass only a correspondingly smaller proportion of the light picked up by the reflector.

Recently, however, projection lenses have been made available which will pass a cone of light approximately 29 degrees in total angular diameter. Such a lens will allow the magnification to be reduced from 6 to 4.5 and still take all the light from a reflector with a gathering angle of 120 degrees about the positive crater. This change would merely require a new reflector of the proper magnification (possibly slightly larger in diameter and further from the arc to allow sufficient room in front of the lamp), the new type projection lens, and the proper carbons and current. The light on the screen would theoretically be increased inversely as the square of the magnification or approximately 75 per cent over that now available. A comparison of the relative sizes of the crater and aperture plate with the two magnifications is given in Figure 44 and Figure 48. It appears that an increase of only 10 amperes in the arc current over that used for the six to one magnification would give the corresponding flexibility and evenness of screen illumination to the 4.5 to 1 magnification. For example, a 14 mm carbon at 50 amperes with the new magnification of 4.5 to 1 would have the same allowable movement around the focal point of the reflector for good screen illumination as a 13 mm carbon at 40 amperes with the six to one magnification. In this manner, 75 per cent increase in light on the screen can be obtained by an increase of only 25 per cent in the arc current.

CHAPTER VIII

Direct Current, High Intensity Arc* with Rotating Positive

THE regular low intensity reflector arc and the super-reflecting arc are being used for projection in theatres of moderate size. In the larger theatres, however, the demand for increased projection light has become so great that, at the present time, only the high intensity D.C. arc can supply the extreme concentration of light necessary to provide the required screen illumination. It therefore seems desirable to describe this type of lamp and to call attention to certain characteristics of high intensity arcs which may help in the solution of the ever present problem of increasing the useful light.

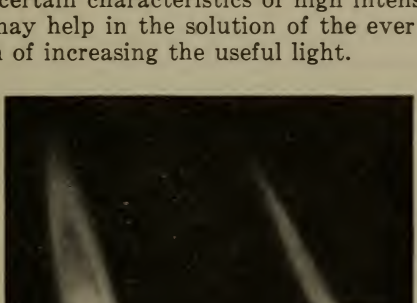


Figure 49
Photograph of Condenser Type, D.C. High Intensity Arc

The light from a high intensity arc, Figure 49, as pointed out in Chapter III, emanates from two distinct sources, the crater and the tail flame. The tail

*This chapter includes a resume of recent papers presented before the S.M.P.E.

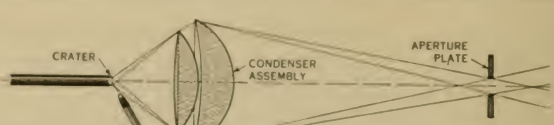


Figure 50
Diagram of High Intensity Arc Lamp — Condenser Type

flame produces about thirty per cent of the total light from this type of arc, but is of no value for projection because it cannot be focused on account of its large size, shape, and position. Therefore, a consideration of the characteristics of the high intensity arc is concerned only with the crater light from the positive carbon.

The very high intrinsic brilliancy of the high intensity arc is attained by adjusting the position of the negative carbon so that the negative arc stream compresses or confines within the crater of the positive carbon a substantial portion of the brilliantly luminescent vapors emanating from that point. This produces a snow-white light of very high candle power, much brighter than it is possible to obtain from incandescent carbon alone. See Figure 21, page 25.

In the condenser type high intensity arc lamp, as indicated in Figure 50, the positive carbon is held in a horizontal position with its creater directly facing the condenser assembly. Since the current density in the carbon is very high and the high efficiency of this type of arc is dependent on the maintenance of a well formed, cup-like crater, the positive carbon is allowed to project but a short distance from the holder and is rotated continuously while the arc is burning. The negative carbon is set at an angle to the positive, usually 40 degrees to 60 degrees below the horizontal.

The feeding mechanism is designed to advance both carbons as they are consumed, and should be

adjusted to feed the positive carbon forward at the same rate it is being burned, thus maintaining the crater at a fixed position in relation to the condenser and to the point of intersection with the axis of the negative carbon. The rate of feed of the negative carbon is also adjustable relative to that of the positive and, when properly adjusted, maintains an arc of uniform length.

High intensity projection lamps are built for operation at current densities appreciably higher than those permissible with other types of projection lamps. The cone of illumination picked up by the condenser assembly being much greater in angular diameter than in the old type, low intensity projection lamp, the efficiency of this type of unit is very high and the volume of projection light available is ample to meet the heaviest demands now being made by the motion picture industry.

The reflecting principle of light concentration, described for low intensity arcs in Chapter VI, has also been applied to the high intensity arc. In all high intensity reflecting arc lamps the positive carbon is held in a horizontal position. In some lamps the negative carbon is inclined at a sharp angle to the positive while in others, the negative is inclined only slightly below the horizontal, as illustrated in Figure 51.

Figure 51
Diagram of High Intensity Reflector Arc Lamp

National High Intensity White Flame Projector Carbons are used for the positive electrode in con-

denser type High Intensity projection lamps and National "High Low" White Flame Carbons in High Intensity Reflector lamps. National Orotip Cored Projector Carbons are used for the negative electrode in condenser type lamps and in most reflector types.

The steady burning of a high intensity arc, whether of the condenser or reflector type, is dependent on the formation of a symmetrical, cup-like crater at the tip of the positive carbon. The formation of this crater on the blunt tip of a new carbon requires appreciable time. For this reason, National High Intensity Projector Carbons are pre-cratered, that is, a cup-like depression is formed at the tip of the carbon in the process of manufacture. This improvement assures quick and smooth burning-in, as well as clean burning, when the arc is struck on a new carbon.

Table IX gives the combinations recommended for different ranges of arc current.

TABLE IX

National High Intensity Projector Carbon Combinations

High Intensity Arc — Direct Current

Arc Amps.	*Approx. Arc Volts*	*Positive Carbon*	*Negative Carbon*
75- 90	54-60	11 mm x 20″ National High Intensity White Flame Projector.	$\frac{11}{32}$″ or $\frac{3}{8}$″ x 9″ National Orotip Cored Projector.
120-130	67-69	13.6 mm x 22″ National High Intensity White Flame Projector.	$\frac{3}{8}$″ or $\frac{7}{16}$″ x 9″ National Orotip Cored Projector.
140-160	70-72	16 mm x 20″ National High Intensity White Flame Projector.	$\frac{7}{16}$″ x 9″ Extra Heavy Coated, National Orotip Cored Projector.
High Intensity Reflector Arc — Direct Current			
60-85	48-58	9 mm x 20″ National "High Low" White Flame Projector.	$\frac{5}{16}$″ x 6″ or 9″ National Orotip Cored Projector.

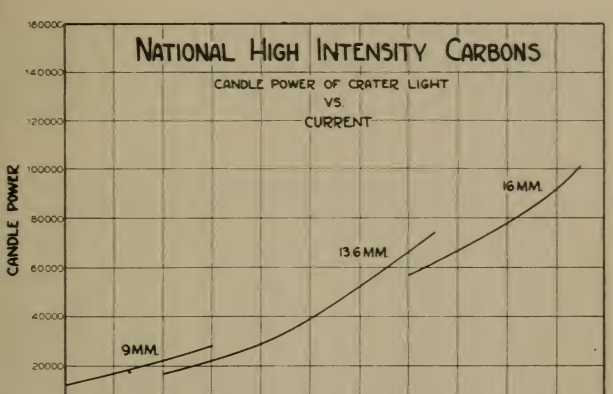


Figure 52
Candle Power of Crater Light vs. Current

A study of the characteristics of the direct current, high intensity arc should include candle power, both directly in front of the arc and at various angles, as well as the area of crater opening and intrinsic brilliancy for the various carbon sizes and operating currents.

The candle power of the crater light directly in front of the arc is shown in Figure 52.

As would be expected, the candle power increases with the current. When the same current is used on two different size carbons of the same composition, the small size carbon, that is the one with the higher current concentration, gives the greater candle power.

The angular distributions of candle power from the positive craters of 9, 11, 13.6, and 16 mm. carbons in the horizontal plane through a total angle of 80 degrees are given in Figure 53 for a number of different currents. The candle power is slightly lower

directly in front of the crater than at 10 degrees to 20 degrees on either side. The candle power holds up remarkably well to the 40 degree limit measured and is only 10 to 17 per cent lower at 40 degrees than at the center.

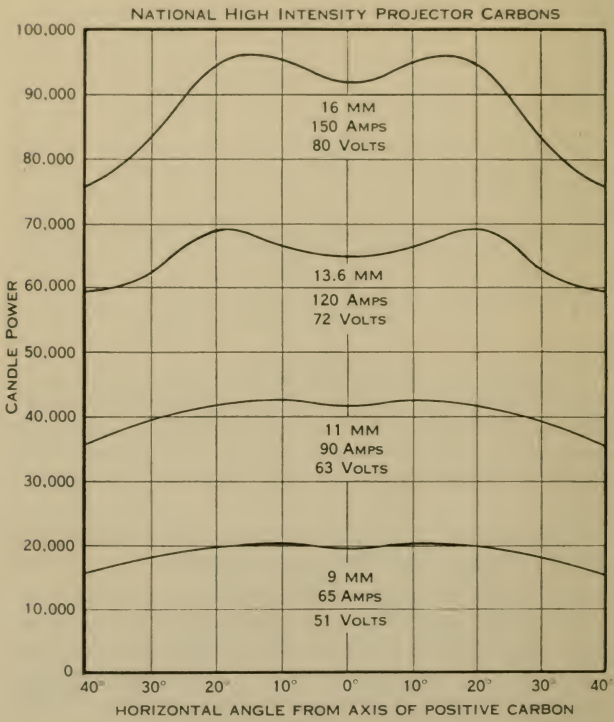


Figure 53
Angular Distribution of Candle Power

The areas of the crater openings of the different size carbons at various currents are given in Figure

54. By "area of crater opening" is meant the area of the circle bounded by the rather sharp lip which surrounds the cup shaped crater in the high intensity arc.

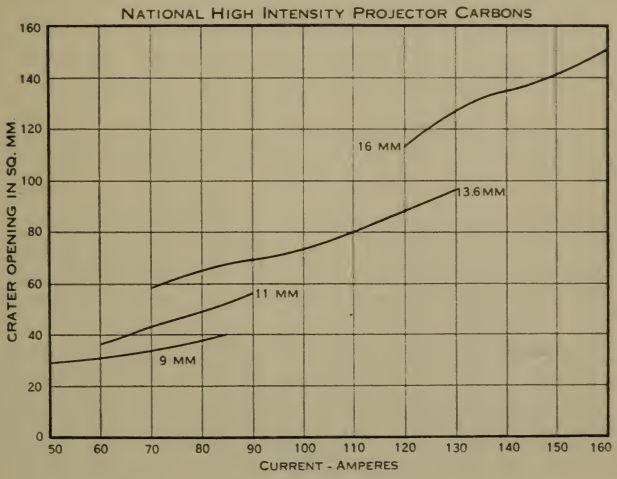


Figure 54

Crater Opening vs. Current

The cross sectional areas of the 9 mm., 11 mm., 13.6 mm. and 16 mm. high intensity carbons are 64 sq. mm., 95 sq. mm., 145 sq. mm. and 201 sq. mm., respectively. It is obvious from the curves that the areas of crater openings for even the higher currents are much less than the original carbon cross section.

The decrease in crater opening for the lower current densities is due in part to the increased spindle or tapering of the portion of the carbon projecting from the positive holder. This increased tapering is due to the decrease in the length of carbon consumed per unit of time with decrease in current, which al-

lows a longer time for the hot surface of the carbon close to the crater to burn away.

The size of the crater opening or light source of the high intensity carbons is important in considering the application of any optical system for it has long been recognized and clearly demonstrated that the light efficiency for motion picture projection decreases rapidly as the area of the light source increases.

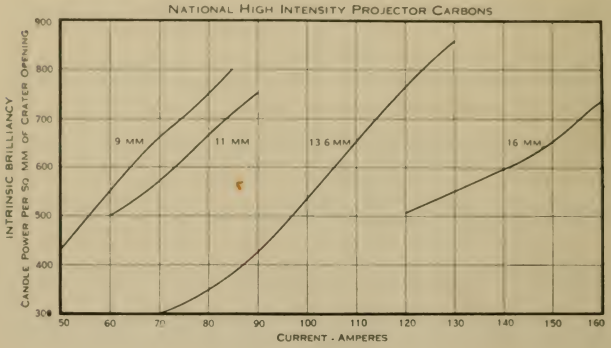


Figure 55
Intrinsic Brilliancy vs. Current

The intrinsic brilliancies in candle power per square millimeter of crater opening are plotted in Figure 55.

As in the case of the candle power, the intrinsic brilliancy increases very rapidly as the current is increased on any given size carbon. It is interesting to note that practically the same intrinsic brilliancies are obtained with the various sizes of carbons at the currents ordinarily used. These values, ranging from 650 to 800 candle power per square millimeter, illustrate quite forcibly the advantage that the high intensity arc has for projection purposes over the plain carbon with an intrinsic brilliancy of 175 candle

power per square millimeter and the incandescent tungsten filament projector lamp run at over-voltage with an intrinsic brilliancy of 27 candle power per square millimeter.

In most commercial lamps the angle formed by the axis of the two carbons is fixed. It is well known, however, that the relative position of the two carbons along their respective axes appreciably affects the behavior of the high intensity arc. The following discussion will show that rather minor variations in position have an important effect on the amount of light and the steadiness of the arc.

The results of these variations are common to all types of high intensity lamps and carbons but most of the observations here discussed, unless otherwise specified, were made of 13.6 mm. positives with Orotip cored negative carbons at 120 amperes.

It has been the practice for carbon manufacturers to specify the current at which high intensity carbons of various sizes should be burned, but they have been reluctant to specify the voltage. A glance at Figure 56 will explain the reason for this reticence.

This figure gives graphic representations of three 70-volt arcs, but the arc lengths, measured as shown in the figure, vary from 1⅛-inch to ⅝-inch. In X the negative flame does not touch the lower part of the positive carbon, in Y it just touches it, and in Z it overlaps it considerably. These arcs give entirely different results in quantity and quality of crater light and the projectionist would only be confused by any voltage specification without qualification as to the relative position of positive and negative carbons, since this latter relationship is probably more important than the arc voltage.

The most practical means of studying the results of the movement of the positive carbon with respect to the negative is to hold the negative carbon tip in one position and move the positive carbon along its axis,

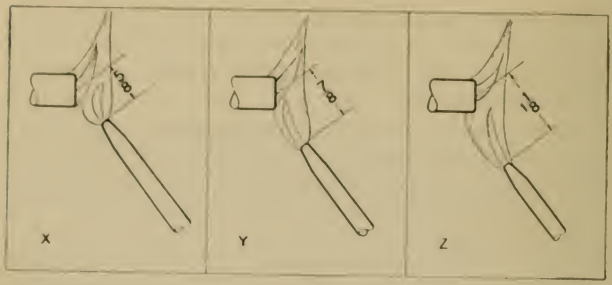


Figure 56

Three 120 Ampere, 70 Volt Arcs

maintaining the current at constant value by adjusting the ballast resistance. Graphic representations of the arcs obtained at 120 amperes by moving the positive carbon successive steps of ⅛-inch along the axis are given in Figure 57.

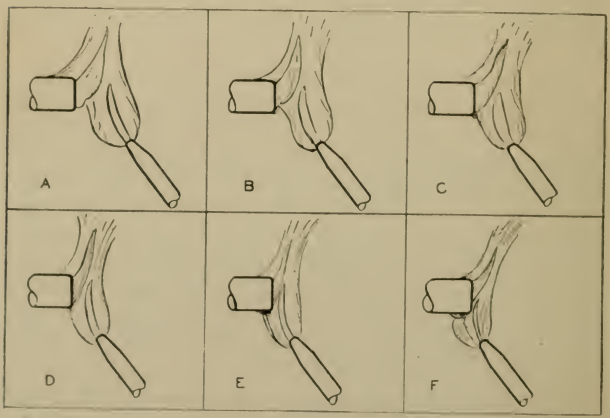


Figure 57

Changes in Arc with Relative Position of Carbons

The arc voltage for this particular set varies from 86 in position A to 55 volts in position F. The negative flame in position A is considerably ahead of the positive so that the positive flame actually rolls out of the bottom of the positive crater before the negative flame strikes it and diverts it upward. As the positive carbon is moved ahead this condition is altered so that at D, the edge of the negative flame just touches the lower edge of the positive carbon and practically the whole negative flame is sweeping across the crater opening as though compressing the positive flame. Finally at F a good portion of the

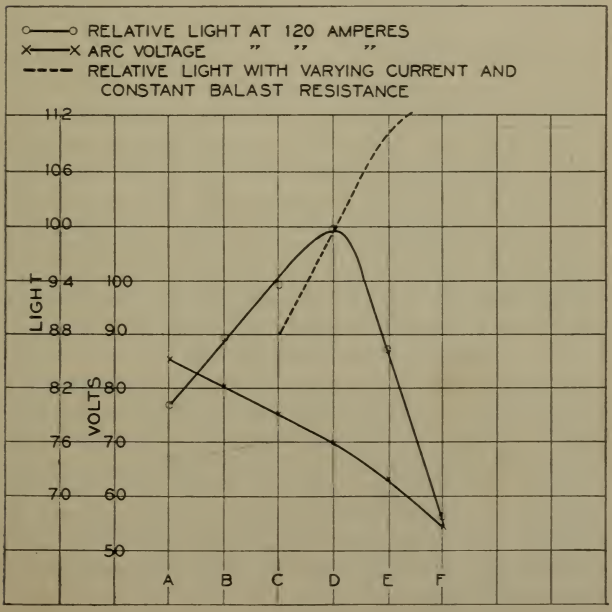


Figure 58

Changes in Light Intensity and Arc Voltage

negative flame plays against the bottom of the positive carbon and again only a part sweeps across the positive crater. The values of relative light and arc voltage for these different arcs at 120 amperes are shown in Figure 58. The maximum useful light is obtained at position D (as would be expected from the above description of the action of the negative flame against the positive crater opening). The light diminishes as the positive is moved in either direction from position D.

The useful light from the arc is steadiest when the edge of the negative flame is definitely on the lower part of the positive crater. To obtain this steadiness with the greatest possible volume of useful light, it is necessary to get as near position D as possible without having the edge of the negative flame periodically slip off the edge of the positive crater. This may require a slight adjustment toward position E.

When this arc relationship is established excellent screen illumination should result. If such is not the case, with the optical system in the customary position, the projectionist should adjust his lenses or lamp until the desired spot on the aperture plate and maximum uniform light on the screen is obtained. He will then be using both his optical system and his arc to the best advantage and the light on the screen will be steady, brilliant and uniform.

If the position of the positive carbon is such that a considerable portion of the negative flame is enveloping the outside of the positive crater, as in position F, the useful light is still very steady but has decreased in amount, as shown in Figure 58. This is probably because an appreciable amount of the current is actually going through the outside of the positive shell rather than through the crater where it generates useful light.

If, on the other hand, the positive is so placed that the negative flame is alternately hitting or missing the lower edge of the positive, as might be the case

with the carbons in position C or D, the useful light is high but there is a small flicker evident whenever the negative flame goes on or off the shell. If the positive is moved still further back as in B or A, so that the negative flame clears the positive shell entirely, there is a decrease in light as indicated by Figure 58, accompanied by undesirable large flickers due to the negative flame not being in position to keep the positive flame and gases consistently in correct relationtion to the positive crater.

If the positive carbon is changed from position C or D to that of E without changing the ballast resistance or the position of the negative, as is often done in the projection booth, there might actually be an increase in light. This, of course, would be accompanied by an increase in arc current. If the positive is moved in the opposite direction toward position A the decrease of light will be much greater than that shown in the solid line of Figure 58. This change is shown by the dotted line in Figure 58 for a 115-volt power line. The reason for this is obvious when the decrease of arc voltage is going from A to F is noted. If the ballast resistance and line voltage were kept constant, a movement of the positive from position A to any of the other positions would necessarily apply an increasing voltage to the constant ballast resistance and give an increase in current.

The distance from the projected axis of the positive carbon to the tip of the negative carbon for the arc illustrated in Figure 57 is $\frac{5}{8}$-inch. Similar experiments were made with the distances of $\frac{1}{2}$-inch and $\frac{3}{4}$-inch with exactly the same results. Within these limits and with the same relative position of the positive and negative flames the arc length had no noticeable effect on the useful light. In the high intensity arc burning 16 mm positives similar results were obtained.

In high intensity reflector lamps having the negative carbon inclined at only a slight angle below the

horizontal, the principles of arc adjustment discussed on the foregoing pages still apply. With the positive crater at the correct distance from the mirror, as indicated by the gauge pin or by the chart at the side of the lamp on which the arc image is projected, the axis of the negative carbon should intersect the face of the positive crater at a point slightly below the center, in most cases about $\frac{3}{32}$-inch. With the arc properly adjusted the negative arc stream will slightly overlap the lower lip of the positive carbon and will maintain this position steadily, producing a projection light free from annoying flicker.

In both the condenser and reflector type it is important that positive and negative carbons be in the same vertical plane, that is, that they be accurately aligned in a lateral direction. It is also important that the positive crater be maintained at the position indicated by the lamp manufacturer. If it is found that a more desirable screen illumination is obtained with the tip of the positive carbon in a different position than that indicated by the gauge pin or arc image chart, the reason will probably be found in the displacement of the condenser assembly or reflector from its correct position. In such case the positive crater should be adjusted to the indicated position and the condenser assembly or reflector moved forward or back until the position is found which affords best illumination. In case the lamp manufacturer supplies specific instructions for making this adjustment, these should be followed. Operation of the lamp with the positive carbon set ahead of its correct position not only reduces the volume of light but may also result in short carbon life. A protrusion of $\frac{1}{8}$-inch beyond the proper setting has been known to decrease the life of the positive carbon as much as ten per cent.

The use of too short an arc gap may make it impossible to adjust the positive carbon feed to the

rate at which that carbon is being consumed. Likewise, if the negative carbon feed is adjusted to feed the negative carbon faster than it is being consumed, the arc will be shortened and the same difficulty encountered.

Feed rollers and the shafts on which they ride must be kept clean and in good condition. If allowed to become worn, the tip of the positive carbon will wabble, producing fluctuation in the screen illumination, distortion of the positive crater and, frequently, interruption of the feed due to the carbon jamming.

Another operating fault, common to high intensity lamps as well as to those of other types, is overloading of the carbons. Carbons should be operated within the recommended current range. If overloaded, short life and spindling are the natural result. Where these faults are encountered the arc current should be checked at once by means of an ammeter whose calibration is known to be accurate.

CHAPTER IX

A.C. High Intensity Arc

TO bridge the gap between the high-intensity and low-intensity arcs, and at the same time to give the small theater the advantage of the snow-white light enjoyed by the larger theatres, has been an object of research in the laboratories of the National Carbon Company for several years. The results of this long research show that it is possible to fill the gap between the high-intensity and low-intensity sources with an arc giving a light with a color very similar to that of the high-intensity arcs.

This result has been accomplished by means of an alternating-current arc burned on the secondary of a specially designed transformer, without the ballast resistance always necessary with direct current, and also without the motor-generator set or rectifier now required in the vast majority of theatres of all classes. This arc is quite different in character from any other arc of which we know today. The sources of light are concentrated into small volumes near the electrode tips, as shown in Figure 59. Either of these small, brilliant light sources can be focused by means of a mirror, and therefore can be used for projection.

Figure 59
A.C. High Intensity Arc

In spite of the fact that practically all the useful projection light comes from only one of these sources, experiments show that with this alternating-current arc at least 15 per cent more light can be projected to a screen with a given optical system and aperture plate than with a low-intensity, direct-current arc using the same line power. Further substantial increase in light output is possible, as discussed at a later point, through improvements in the optical system to which this arc is especially well adapted. The color of the screen light from this alternating-current arc is snow-white, resembling that produced by the direct-current, high-intensity arc.

TABLE X

Characteristics of Copper-Coated A.C. High Intensity Carbons

	8 *mm* x 12″	7 *mm* x 12″	6 *mm* x 10″
Current (Amperes)	75-80	60-65	40-45
Approximate Arc Voltage	24-29	23-26	22-25
Consumption (Inches per Hour)	4.0-5.5	4.0-5.5	4.0-5.5
Current Density (Amps. per Square Inch)	960-1025	1000-1090	910-1030

The A.C. high-intensity projection arc is essentially a high current-density, low voltage arc. At the rated currents shown in Table X, the current density (910-1090 amps. per sq. in. of carbon cross-section) is very much higher than that of the mirror arc carbons (140-188 amps. per sq. in.) and somewhat higher than even that of the D.C. high intensity positive carbons (450-900 amps. per sq. in.). Another difference is that in the conventional D.C. high-intensity lamp the positive carbon is gripped at a point close to the arc, and rotated during operation, whereas in the A.C. high-intensity lamps both

carbons are clamped near the holder end and neither is rotated. It is therefore necessary to increase the conductance of the electrode by coating it with metal, which in this case is copper. The copper does not enter the arc stream, its main function being to furnish a low-resistance path for the current from the carbon holder to a point near the arc. It also protects the carbon from oxidation. Figures 60 to 65 illustrate the performance of the A.C. high-intensity arc under different operating conditions. These illustrations are all traced from actual arc images and show the true relationship between the different elements of the arc.

If the current is too great, the copper will melt to a considerable distance from the arc, as shown in Figure 60. The arc then becomes unsteady and is apt to blow out. Also, the arc voltage and consumption of the carbons are increased to such an extent that they may be outside the range of control of the arc-feeding mechanism. If, on the other hand, the current is too low, the copper will not melt away as far from the arc, the light will be very much reduced, and the current and voltage will not be constant. This condition results in an unsteady arc, which "flops" from the top to the bottom of the carbon, as illustrated in Figure 61. If the recommended current and voltage limits are observed neither of these undesirable conditions will be encountered.

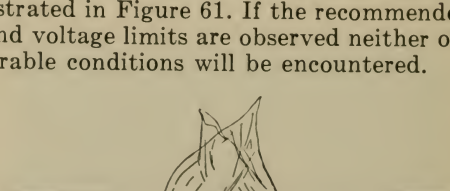


Figure 60

8 mm A.C. High Intensity Carbons, Overloaded: 90 Amperes, 35 Volts

Figure 61

8 mm A.C. High Intensity Carbons, Underloaded: 60 Amperes, 24 Volts; Showing Different Positions of the Arc as it "Flops" About on the Ends of the Carbons

It is essential for good operation of the arc and good light projection that the A.C. high-intensity arc be maintained within certain definite arc lengths and that it have a characteristic shape which is easily identified. Figure 62 shows the A.C. high-intensity arc burning under the correct conditions at 80 amperes and 25½ volts between two 8 mm carbons. The copper coating ends 0.35-inch from the ends of the carbons, the arc length is 0.27 inch and the end of the electrode is 0.225-inch in diameter. The arc itself consists of a highly luminous portion close to each electrode, and a portion of lower luminosity, almost the shape of a ball, extending about as far below the electrodes as above them and ending at the top in two well-defined short tail-flames. It is interesting to note the shape of the highly luminous portion of the arc near the electrodes to which reference will be made later in discussing improvements in the optical system.

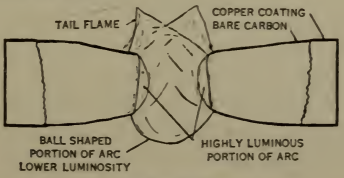


Figure 62

8 mm A.C. High Intensity Carbons: 80 Amperes, 25½ Volts; Good Operating Conditions

If the arc length is decreased it will hold essentially the same arc shape, if the operating conditions are favorable, until it reaches approximately 0.23 inch or 24 volts. Figure 63 (A) illustrates the arc just before that point, with a good burning condition; and (B) the arc just after that point, with a shorter arc length and poor burning conditions. When the arc length is 0.23-inch the arc stream begins to be turbulent. The two tail-flames and the highly luminous portion of the arc close to the electrodes lost their identity, and the whole arc assumes a boiling and seething appearance. There is rapid flicker; the arc voltage and current are erratic; and in addition, at such very short arc lengths there is a noticeable shadowing effect from the electrodes themselves.

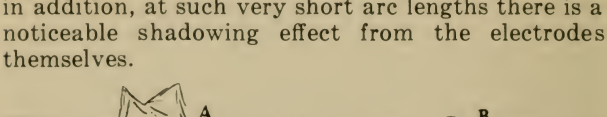


Figure 63

8 mm A.C. High Intensity Carbons: 80 Amperes, 23 to 24 Volts; (a) *Short Arc Length, Good Operating Conditions;* (b) *Short Arc Length, Poor Operating Conditions*

If the length of the arc is increased beyond that shown in Figure 62 the form of the arc will be sustained if the operating conditions are suitable, until the length is approximately 0.35-inch. Figure 64 (A) shows the arc immediately before, and (B) after, such a point has been reached. At and beyond that length, the arc has a tendency to be swept upward, so that the lower part no longer bows down appreciably, and the upper part and the tail-flame become greatly extended. The highly luminous portions close to the electrode likewise becomes distorted, as shown in (B). The arc is unstable to such an extent that it will repeatedly jump back and forth between the positions shown at (A) and (B).

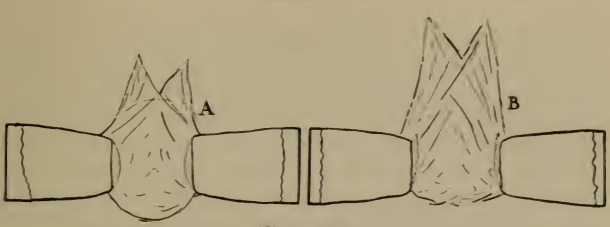


Figure 64

8 mm A.C. High Intensity Carbons: 80 Amperes, 28 to 29 Volts; (a) *Long Arc Length, Good Operating Conditions;* (b) *Long Arc Length, Poor Operating Conditions*

Another arc condition that must be considered and, if encountered, corrected, is shown in Figure 65. The arc is of medium length, and would ordinarily have the normal appearance of Figure 62, but is disturbed by external forces, and has the tendency to snap back and forth between that position and the one shown in this figure, causing variation of the current and voltage, flicker, and uneven light distribution. This condition may be caused by too strong a draft in the lamp, or by an unbalanced magnetic effect due to a poor arrangement of the current leads; or by other means that would tend to distort the arc.

If we assume that the design of lamp house, the draft, and the arrangement of leads are such as to

Figure 65

8 mm A.C. High Intensity Carbons: 80 Amperes, 26 Volts; Medium Arc Length, Arc Disturbed by External Forces

avoid the above conditions, the 8 mm A.C. high-intensity carbons at 80 amperes will exhibit good burning characteristics for arc lengths between 0.23-inch and 0.35-inch, and from approximately 24 to 29 volts. There will, however, be a noticeable change of light intensity between those extreme limits, so that the permissible range of variation in arc length and voltage from moment to moment is much less than the complete range of satisfactory performance.

At 75 amperes the arc lengths that will give good burning characteristics with the 8 mm carbons are essentially the same as those for 80 amperes, and the arc voltage is approximately one volt lower. The 7 mm A.C. high-intensity carbons are rated from 60 to 65 amperes. The corresponding conditions for good operation are an arc gap of 0.21-inch to 0.31-inch, and an arc voltage of approximately 23 to 26 volts.

One of the objectives of good projection is to maintain a light of uniform intensity and good distribution on the screen at all times. As has been pointed out in the case of other types of arcs, the light on the projection screen is dependent on both the arc itself and the position of the arc in relation to the optical system. This applies also to the A.C. high-intensity arc.

The lamps using this carbon ordinarily have a horizontal trim, with the carbon tip facing the back of the lamp held at the focus of an elliptical reflector that projects the light picked up from the carbon and arc onto the aperture and film. These lamps are provided with a device that throws an image of the arc on a white card, on which the correct arc length and arc position with respect to the mirror are indicated. They also have a method of feeding and adjusting the arc that keeps the carbons in the proper position with respect to each other and the optical system, provided the lamp is operated properly and

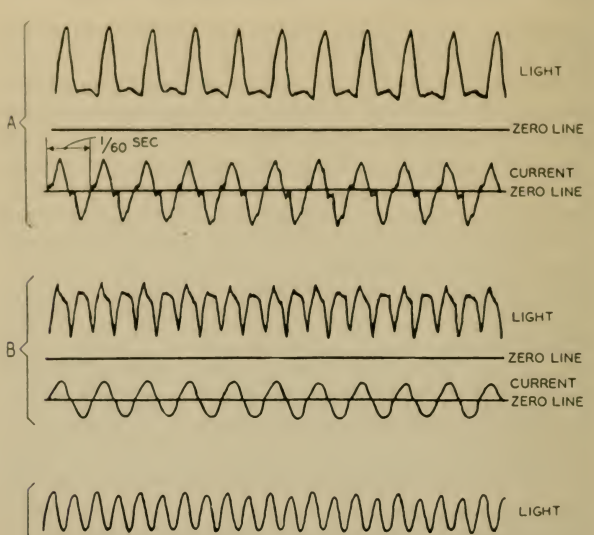
the projectionist pays a reasonable amount of attention to the arc image.

It is highly important that the tip of the carbon facing the reflector be kept at the proper distance from the reflector. Variation, in either direction, from the correct position causes a sharp decrease in the total light on the screen and may result in disturbing contrast of brightness between the center and edges of the screen. The feed mechanism of the lamp should be adjusted, at the same time, to maintain uniform arc length. While moderate variation of arc length does not seriously disturb the volume of light nor the distribution of light on the screen, as long as the arc current and position are maintained constant, too short an arc length results in poor light distribution and erratic performance of the arc.

Increasing the arc current increases the total light on the screen without materially affecting the light distribution. For satisfactory performance it is essential, however, that the arc current be kept within the recommended limits for the trim in use.

There has been considerable discussion concerning the possibility of a beat or fluctuation in the light on the projection screen from the A.C. high-intensity arc. This idea is based on the results that were formerly obtained when the low-intensity A.C. arc was used for projection. It will be shown that the present high-intensity A.C. arc is not the same as the old type low-intensity A.C. arc with neutral cored carbons, but is a new type of arc producing a light on the screen more comparable in wave-form to the light from the low-intensity D.C. arc operated by a rectifier.

Oscillographic pictures of the current and light on the screen without the shutter running are shown in Figure 66 for the low-intensity A.C. arc, the high-intensity A.C. arc and the rectified low-intensity arc. The instantaneous light on the screen was measured by means of a photoelectric cell and an amplifying



A. Low-intensity 60-cycle alternating-current arc
B. High-intensity 60-cycle alternating-current arc
C. Low-intensity rectified-current arc

Figure 66

Oscillograms of Arc Current and Instantaneous Light on Projection Screen; Projector Shutter Not Running

system that allowed a linear relation between the cell current and the output current, which was, in turn recorded on the oscillograph coincidentally with the instantaneous value of the arc current.

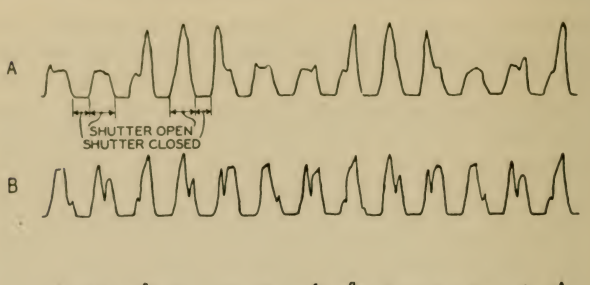
The direction of the current in the *low-intensity A.C. arc* changes every half cycle in the usual manner. The light emanating from the arc, as indicated in the figure, rises to a peak when the carbon that is

in focus is positive, and decreases and remains at a low value as the direction of the current changes and the carbon in focus becomes negative for half a cycle.

With the *low-intensity D.C. arc*, operated by a single phase rectifier, the current is unidirectional, but decreases to a zero point during each half cycle. The light on the screen rises to a peak at the middle of each half cycle, but decreases to about half that value as the current approaches the zero point, rising again to a peak, which is not quite so high as that in the first half of the cycle, and decreasing to a low value again. In other words, there is a fluctuation, but the light during each half cycle rises to very nearly the same level.

The current in the *A.C. high-intensity arc*, of course, changes its direction in the usual way, but the light on the screen is considerably different from the light of the low-intensity A.C. arc. Instead of remaining at a low value while the carbon in focus is negative, the light rises to approximately the same value as it does when the carbon in focus is positive, but the shape of the light curve is slightly different. In other words, except for certain differences in the shape of the curve, the light projected by the high-intensity A.C. arc approximates that of the rectified current arc much more closely than it does the light of the low-intensity A.C. arc.

The effect of the light-wave is very noticeable when the shutter mechanism is operating. It can be seen in Figure 67 that the amount of light on the screen from one shutter opening to the next varies enormously in the case of the *low-intensity A.C. arc*. This is due directly to the fact that, as illustrated in the preceding figures, during the half cycle that the carbon in focus is negative, the light remains at a comparatively low value. On the other hand, the light from the *high-intensity A.C. arc*, although of irregular wave-form, is much more nearly constant for each shutter opening, and corresponds much



A. Low-intensity 60-cycle alternating-current arc
B. High-intensity 60-cycle alternating-current arc
C. Low-intensity rectified-current arc

Figure 67

Oscillograms of Instantaneous Light on Projection Screen; Two-Bladed Shutter, 1440 r.p.m., Corresponding to Film Speed of 90 Feet Per Minute

more closely to the curve of the light obtained from the *D.C. arc* operating on rectified current with the shutter running.

The practical proof of this is obtained by observing the projection of the same amount of light from the three types of arcs with the shutter running. This has been done in the laboratory with a very high degree of illumination on the screen and without film in the projector, the conditions under which fluctuations in light are most noticeable. Observations under such conditions agrees with the conclusions arrived at from the oscillograms; namely, that the light beat or fluctuation of the high-intensity A.C. arc is very much less than that of the low-intensity A.C. arc and of essentially the same magnitude as that of the low intensity D.C. arc using neutral cored carbons and operated by a single phase

rectifier. From the standpoint of practical projection, the beat or fluctuation of light is so small that under reasonable conditions it cannot be considered detrimental to the quality of the picture.

Further information on the lamps developed for the use of A.C. high intensity carbons is contained in the closing paragraphs of the following chapter.

CHAPTER X

"Suprex" Type High Intensity Arc

ANOTHER type of light source has taken its place with the A.C. high intensity arc in bridging the gap between the low-intensity and the larger high-intensity arcs. This is the Suprex arc. This new type of arc operates on direct current, and employs a series of high-intensity carbons smaller in diameter and operating at lower arc currents than have hitherto been used for high intensity projection. The carbons have been designed so that, with a few simple precautions, the positive carbon does not need to be rotated and the negative carbon can be coaxial with the positive. The carbons are protected from oxidation, and their electrical resistance is reduced by a copper coating that makes it practicable to hold the carbons any convenient distance from the arc. These carbons burn with the same crater formation, and give the same brilliant snow-white light on the screen as the larger, uncoated, high-intensity D.C. carbons.

The consumption and current-carrying capacity of the carbons for the new Suprex type lamps are given in Table XI.

TABLE XI
National "Suprex" Carbon Combinations

Carbons	*Current Range*	*Voltage Range*	*Consumption — Inches per Hour*		*Effective Pos. Crater Diam.— Inches*
			Positive	*Negative*	
6 mm x 12″ Suprex Cored Positive 5 mm x 9″ Suprex Solid Negative	32-40	31-40	6.5-13.5	3.0-4.5	0.14-0.16
7 mm x 12″ Suprex Cored Positive 6 mm x 9″ Suprex Cored Negative	42-50	31-40	6.5-13.5	3.0-4.5	0.15-0.20
8 mm x 12″ Suprex Cored Positive 6.5 or 7 mm x 9″ Suprex Cored Negative	56-65	31-40	6.5-13.5	3.0-4.5	0.20-0.25

The carbons in the Suprex type lamps are both held in a horizontal position, and the magnetic field, resulting from the current through the carbons, is of equal strength on all sides. The tail flame of the arc therefore surrounds the positive crater in an almost uniform layer, as shown in Figure 68. This condition lacks stability and slight disturbances may cause the crater to burn off on one side and produce a noticeable change in the light on the screen. In some of these lamps an auxiliary magnetic field has been introduced which augments the magnetic flux below the arc and opposes that above it. This gives the tail flame a definite upward trend, as shown in Figure 69, and assures greater stability to the position of the arc stream and the form of the crater. The axis of the negative carbon is placed slightly below that of the positive to compensate for the angular direction of the arc stream.

The improvement in the steadiness of screen illumination resulting from the use of this auxiliary magnetic flux is very noticeable, especially when the lamp is operated from a 115-volt line through a large ballast resistance. It is, of course, essential that this field be of the right direction, and care must be taken,

Figure 68
Suprex Arc Without Supplementary Magnetic Field

Figure 69

Suprex Arc With Supplementary Magnetic Field and With Axis of Negative Carbon Slightly Lowered

when making any repairs to the lamp, to see that the direction of this auxiliary flux is not reversed.

Distance from positive crater to reflector is the most important item in the control of this arc. Variation in this distance causes decided variation in both the total screen light and the contrast in brightness between center and edges of the screen.

Ratio of positive-to-negative carbon feed should be adjusted so that uniform arc length and position can easily be maintained at the desired operating current. Increasing arc current increases positive-to-negative ratio of carbon consumption and calls for corresponding adjustment of feed ratio.

Increasing arc current increases total screen light but does not greatly affect the light distribution, that is, does not greatly modify the relative intensity of illumination at center and edges of the screen. Arc current should be held within the recommended limits for the trim in use.

Variation of arc length does not appreciably affect the total light on the screen nor its distribution, provided the arc current and position of positive crater remain unchanged. Extreme variation of arc length, however, introduces operating difficulties.

The most satisfactory source of power is a constant voltage source near enough to the arc voltage to permit the use of a small ballast resistance or a source with a falling volt-ampere characteristic and a no-load voltage not greatly in excess of the arc voltage. Several different types of units are now on the market which have characteristics suitable for these non-rotating, high-intensity, D.C. arcs. Each has its own peculiar advantages but all are characterized by a comparatively large increase of current with a decrease in arc voltage.

With a suitable source of power and proper adjustment of the control mechanism for the conditions under which the arc is operated, these new Suprex type, D.C., high-intensity arcs supply to the smaller theatres all the advantages of light quality and intensity which the higher amperage high-intensity lamps have given the larger theatres. They produce 100 to 200 per cent higher levels of screen illumination than is available from the low-intensity D.C. mirror arc and at a lower operating cost per unit of light volume.

These later type high intensity arcs, the A.C. high intensity arc and the Suprex type D.C. arc, give best projection within a relatively narrow range of arc position. This requires a control mechanism adapted to maintaining the position of the arc within these limits and, in the case of the Suprex type lamps, providing a fairly wide range of positive-to-negative feed ratio. This result is very effectively accomplished by most of the lamps now on the market so that the projectionist, with reasonable attention, should encounter no difficulty in maintaining proper operating conditions at the arc.

In the design of the new lamps, both A.C. and D.C., advantage has been taken of the fact that the brilliant gas ball from which the light emanates projects somewhat beyond the lip of the crater. As a result, the light at 90 degrees, that is, at right angles

to the trim, is much higher for these high intensity arcs than for the low intensity arc where the highest brilliancy is confined to the crater floor. This fact, together with the development of a projection lens, accepting a much wider cone of light than was formerly possible, has led to the use of reflectors having a larger angle of light pick-up than those used in the low intensity D.C. mirror arc lamps.

From the foregoing facts, it is evident that the needs of the smaller theatres for projection light of higher intensity and better quality have been met effectively and efficiently by the A.C. high intensity and Suprex type arcs. Screen illumination 60 to 200 per cent greater than that obtainable from the low intensity arc has been provided. The increase in operating cost is so small that it is readily absorbed by the improved patronage which high intensity projection and a more comfortable level of general illumination attract.

CHAPTER XI

Summary of Operating Precautions

THE modern motion picture projector is a very reliable mechanism. Although subjected in some instances to intense heat it will, if given proper care, last a long time and give excellent service. It is essential, however, that reasonable attention be given to the maintenance of all elements of the projector and particularly to the projection lamp. For that reason this chapter is devoted to a résumé of operating precautions which will aid the projectionist in obtaining maximum efficiency and reliability in the operation of projection lamps.

It is highly important that the correct type and combination of carbons be used. Projector carbons are manufactured to meet the specific requirements of a certain type of lamp and the combinations recommended have been carefully determined by laboratory and service tests. Best results can be obtained only when these recommendations are followed.

Carbons should always be stored in a dry place. They are porous and will absorb moisture if stored in a damp location, with the result that sputtering at the arc will be experienced. National Projector Carbons are thoroughly dry when they leave the factory but there is always the possibility of exposure to dampness during shipment or storage. For this reason, the practice of some projectionists of laying a few carbons in the lamp house or on top of a rheostat before burning is to be commended. Carbons are not perishable. A damp carbon, after being thoroughly dried, is as good as ever.

Carbon holders must be kept clean and their contact with the carbons firm. The projectionist should give frequent and careful attention to the holders, removing all effects of corrosion or burning so that

smooth, firm contact of full area is maintained. Defective contact between carbons and holders is a frequent cause of spindling.

It is likewise essential that feed rollers on high intensity condenser and high intensity reflector lamps be kept clean and in good condition to insure steady and accurate rotation of the positive carbon, maintain a symmetrical crater, and prevent possibility of jamming.

Carbons should always be operated within the recommended current range. If operated at a current lower than that recommended, the efficiency is greatly reduced for reasons that have been explained in detail in preceding chapters. Currents above the recommended range cause spindling, short life and unsteady burning, with very little advantage in the form of increased volume of projection light.

Carbons must be kept in proper alignment. Poorly formed craters and lowered efficiency of light production are invariably encountered when the correct alignment of the carbons is not maintained. If the allowance for movement of the carbon holders is insufficient to establish exact alignment, the desired results can usually be obtained by the use of shims. Particular attention should be given to the lateral alignment of the carbons.

It is equally important, in attaining full efficiency of light production, that the crater of the positive carbon be kept in the correct position relative to the optical system. Modern lamps are equipped with gauge pins or with means for projecting the arc image on a chart at the side of the lamp housing which indicates the correct location of the positive crater. The feed of the positive carbon should be regulated to maintain the crater as near as possible to this position throughout the burning period. The feed of the negative carbon should also be adjusted to maintain correct and uniform arc length during

operation. In some types of lamps, having automatic feed, operation with too short an arc prevents adjustment of the feed mechanism to a point which maintains the carbons in proper relative position.

If it is found that a more desirable screen illumination is obtained with the positive crater out of the indicated position, it will usually be found that the condenser or reflector has also been displaced. In such cases, the optical system should be adjusted so that best results are obtained with the positive crater in the position indicated as correct.

The lamp housing and mechanism should be cleaned regularly and thoroughly and all moving elements of the lamp mechanism kept well lubricated with oil or grease of the consistency recommended by the lamp manufacturer. Complaints sometimes arise from hard grease clogging the feeding mechanism and interfering with the feeding of the carbons. Such troubles can be eliminated by cleaning out the hard grease and replacing with a grade of the proper consistency.

Keep condensers and reflectors clean and well polished. When reflecting mirrors begin to show disintegration of the silver coating or a grayish color, they should be resilvered.

Instructions for adjusting the position of the optical elements of the lamp are provided by the manufacturer. These should be carefully followed when the lamp is installed and the correct position maintained by adjustment whenever necessary.

Alignment of the lamp with the projection head should be checked from time to time and adjusted when found incorrect.

Keep all electrical contacts throughout the lamp circuit clean and firmly tightened so that full area of contact is maintained.

Particular attention to the care of electrical instruments will be well repaid. Ammeters, voltmeters and

wattmeters are necessarily of somewhat delicate construction and the best instrument may be ruined by misuse.

Meters should never be placed where they will be exposed to high temperature, vibration, or strong magnetic fields. Such conditions may quickly impair their accuracy.

They should be calibrated at regular intervals, at least once a year.

The projectionist should not attempt to adjust or repair electrical meters. When attention is required they should be returned to the manufacturer who has proper facilities for making the needed repairs and adjustment.

Make sure that the contacts on all external connections to electrical meters are clean and firmly secured.

Damage to rheostats sometimes results from operation with a short arc at an arc voltage appreciably below normal. This practice throws on the rheostat a greater proportion of the line voltage than it is designed to carry, so that the arc current can be held down to normal value only by cutting out some of the parallel connected resistors. This may force the remaining resistors to absorb so much wattage in excess of their radiating capacity that destructive temperatures result. With correct arc adjustment, ample range of current control should be afforded by normal operation of the rheostat.

Careful attention to the foregoing precautions, and to the more specific instructions given in earlier chapters for the type of lamp in use, will afford the projectionist using National Projector Carbons screen illumination of maximum steadiness, brilliancy and uniformity.

CHAPTER XII

Carbon Arc Spot and Flood Lamps, Stereopticon and Effect Machines

THREE types of carbon arc spot and flood lamps are on the market. These are the low intensity A.C., low intensity D.C. and high intensity D.C. types. In the low intensity lamps, both A.C. and D.C., the upper and lower carbons are mounted in line with each other and inclined several degrees from the vertical, as illustrated in Figure 22, page 28. The carbons are usually controlled by hand feed.

In the high intensity, D.C. spot and flood lamp the positive carbon is held in a horizontal position with the negative inclined at sharp angle, as in the high intensity projection lamp, Figure 50, page 60. The carbon feed mechanism is usually motor driven with automatic control.

Stereopticon and effect machines in common use are of two types, the low intensity, D.C. carbon arc and the high intensity, D.C. carbon arc. Both types use the "inclined vertical" trim illustrated in Figure 22 and are usually equipped with automatic, motor driven, carbon feed mechanism. An appreciably whiter light is obtained from the high intensity carbon trim than that produced by the low intensity type.

The direct current, low intensity reflecting arc principal is used in the dissolving slide projector. In this lamp the carbon trim is horizontal, as in Figure 35, page 40, and the carbon feed automatic, with motor drive.

The types of carbons used in the foregoing lamps are the same as those used in corresponding types of projection lamps and the instructions given in preceding chapters for the care and operation of the several types of arcs apply, as well, to the lamps here described. Carbon trims and recommended ranges of current are given in Table XII.

TABLE XII
A.C., Low Intensity, Spot and Flood Lamp

Amps.	*Approx. Voltage*	*Upper Carbon*	*Lower Carbon*
30-60	35	5/8" x 12" Nat'l White Flame A.C. Proj.	5/8" x 6" Nat'l White Flame A.C. Proj.
60-80	35	3/4" x 12" Nat'l White Flame A.C. Proj.	3/4" x 6" Nat'l White Flame A.C. Proj.

D.C., Low Intensity, Spot and Flood Lamp

Amps.	*Approx. Voltage*	*Polarity*	*Size and Kind*	
			National Cored Projector	*National Orotip Cored Projector*
30-40	52-54	Positive	5/8" x 12"	-------
		Negative	1/2" or 9/16" x 6"	-------
40-50	54-56	Positive	5/8" x 12"	-------
		Negative	-------	5/16" x 6"
50-55	56-57	Positive	3/4" x 12"	-------
		Negative	5/8" x 6"	or 5/16" x 6"
55-65	57-59	Positive	3/4" x 12"	-------
		Negative	-------	11/32" x 6"
65-70	59-60	Positive	7/8" x 12"	-------
		Negative	-------	11/32" x 6"
70-85	60-63	Positive	7/8" x 12"	-------
		Negative	-------	3/8" x 6"
85-100	63-66	Positive	1" x 12"	-------
		Negative	-------	3/8" or 7/16" x 6"

D.C., High Intensity, Spot and Flood Lamp

Amps.	*Approx. Voltage*	*Positive Carbon*	*Negative Carbon*
85-95	58-62	11 mm x 20" National High Intensity White Flame Projector	11/32" x 9" National Orotip Cored Projector
100-110	63-66	13.6 mm x 22" Nat'l High Intensity White Flame Projector	3/8" x 9" National Orotip Cored Projector
110-125	66-68	13.6 mm x 22" Nat'l High Intensity White Flame Projector	7/16" x 9" National Orotip Cored Projector

TABLE XII — Continued

D.C., Low Intensity, Stereopticon and Effect Machines

Amps.	*Positive Carbon*	*Negative Carbon*
40-50	5/8″ x 6″ National Cored Projector	5/16″ x 6″ National Orotip Cored Projector
50-55	3/4″ x 6″ National Cored Projector	5/16″ x 6″ National Orotip Cored Projector
55-65	3/4″ x 6″ National Cored Projector	11/32″ x 6″ National Orotip Cored Projector

D.C., High Intensity, Stereopticon and Effect Machines

Amps.	*Positive Carbon*	*Negative Carbon*
60-65	11 mm x 6″ Copper Coated National High Intensity W. F.	5/16″ x 6″ National Orotip Cored Projector

D.C., Reflector Arc, Dissolving Slide Projector

Amps.	*Approx. Voltage*	*Polarity*	*Size and Kind*		
			National Cored Projector	*National Solid Projector*	*National SRA Cored Projector*
15-20	54-57	Positive	10 mm x 8″	--------	--------
		Negative	7 mm x 8″	7 mm x 8″	--------
21-25	54-57	Positive	12 mm x 8″	--------	--------
		Negative	8 mm x 8″	--------	--------
26-30	54-57	Positive	13 mm x 8″	--------	--------
		Negative	9 mm x 8″	--------	--------
28-32	54-57	Positive	--------	--------	12 mm x 8″
		Negative	--------	--------	8 mm x 8″
32-42	54-57	Positive	--------	--------	13 mm x 8″
		Negative	--------	--------	8 mm x 8″

CHAPTER XIII

Brushes

MOST theatres are located in districts where direct current power supply is not available. In such cases, the operation of D.C. projection lamps requires the installation of some type of rectifying or converting device to change the alternating current supplied by the power lines to direct current for use at the arc. In most theatres a motor-generator set or some type of synchronous converter is used for this purpose and carbon brushes are required on the D.C. side of all machines of this type.

Reasonable attention to factors affecting the operation of brushes will be well repaid by the improved results and greater reliability of operation thus obtained.

As is true of all rotating equipment, careful attention should be given to the thorough lubrication of bearings. At the same time, care should be exercised to prevent oil getting on the commutator of the machine where it has a tendency to impair the mica insulation of the segments as well as interfering with the operation of the brushes.

The maintenance of uniform air-gaps, under commutating poles as well as main field poles, is essential to good commutation and normal output from the machine. Worn bearings and loose pole pieces are the most common sources of inequalities in the air gaps. When operating troubles are encountered the air-gaps should at once be checked under all pole faces and, if found unequal, the cause determined and the fault corrected.

Accurate alignment of the edges of the brushes with the commutator segments and equal spacing of brushes around the periphery of the commutator are likewise essential to good commutation and cool operation of the unit. A convenient way to check

brush spacing is to wrap a strip of paper tightly around the commutator and, with a pencil, mark the point at which the corresponding edge of each brush bears on the strip. Measuring the distance between these marks will then show whether or not the brush spacing is equal. If found unequal, this condition should be corrected, the method of correction depending on the construction of the machine.

It is obviously important to keep the brush holders and their supporting studs firmly secured. Loose brush holders permit vibration and displacement of the brushes from the correct position.

When new brushes are installed they should be sanded in to fit the commutator accurately. A good way to do this is to cut strips of sandpaper slightly wider than the brush. Raise a brush and place the strip of sandpaper under it with the rough side against the carbon. Let the brush down on the sandpaper and pull the latter through in the same direction as the commutator rotates, repeating this operation until all of the brushes have been sanded to full contact from edge to edge. It is not advisable to pull the strip of sandpaper back and forth under the brush as there is some play of the brush in its holder and this method of sanding tends to form a double face which prevents full contact from edge to edge.

The tension on all brushes should be as nearly the same as the adjustment provided on the brush holders will permit. The actual value of the tension should conform to the recommendation of the manufacturer of the brush grade in use. In most cases, a pressure of two pounds per square inch of brush contact face will give good results.

Maintenance of a good commutator surface merits careful attention on the part of the operator. Burned bar edges, streaks and minor defects in commutator surface can usually be removed by polishing with a commutator stone or with fine sandpaper secured to

a block which has been formed to the radius of the commutator. Serious flat spots or deep grooves, however, required turning or grinding of the commutator. This should be done by a shop properly equipped to handle work of this character. It is never advisable to attempt the removal of an appreciable amount of metal from the commutator by means of a hand stone or sandpaper block since it is almost impossible to maintain a true cylindrical surface by this method. After surface defects have been removed and the commutator smoothed with stone or sandpaper block, it is good practice to burnish the surface by holding a maple or other hardwood block against it under heavy pressure while the commutator is revolved at full speed. This removes minute irregularities and the jagged edges of the fine grooves left by the grinding stone or sandpaper. If this is not done, the brushes may wear down rapidly until they have had time, of themselves, to accomplish a like result.

The undercutting of mica insulation below the surface of the copper segments of the commutator is now a generally accepted practice and has eliminated many of the difficulties experienced on so-called flush mica commutators. Mica and copper are so different in physical charateristics and are subject to such divergent effects from the influence of load and commutation currents that it is difficult to prevent the copper bars wearing or burning below the edges of mica. Undercutting the mica removes this hazard and insures firm electrical contact between brushes and commutator.

Undercutting may be effected by means of a three-cornered file or by scraping out the mica with a hacksaw blade. Where much of this work is done, however, small rotary cutters driven at high speed, are generally used. Care should be exercised to make a clean cut and not damage the mica below the depth of the slot. The depth of the slot should not exceed

$\frac{1}{16}$-inch. A good rule to follow is to limit the depth to the thickness of the insulation. "V" shaped slots have the advantage that little opportunity is offered for the subsequent accumulation of deposit. They are worn off more readily than square or "U" shaped slots, however, and the latter are often preferred since less frequent reslotting is required. Whatever the shape of the slot, the adjacent edges of the copper segments should be slightly chamfered, all projecting fins of mica that might make contact with the brush face carefully removed and the commutator surface lightly sanded and burnished in the manner described in a preceding paragraph to remove any burrs or ragged edges left on the copper segments by the undercutting tool. Slotted commutators should be inspected frequently and any deposit in the slots removed. A thin strip of hard fibre makes an excellent tool for this purpose. Accumulation of copper or carbon dust in the slots may cause damaging short circuits.

Until the commutator of a new machine becomes thoroughly seasoned, there is possibility that the segments may loosen and high or low bars become apparent. The clamp or "V" ring of the commutator should be examined from time to time and, when evidence of looseness is discovered, firmly tightened. This should be done when the machine is hot. Any evidence of failure of the mica insulation of the commutator segments should also receive immediate attention.

In addition to equal spacing of the brushes, their position in relation to the field poles has a vital influence on commutation. On generators with interpole windings this neutral position has a very narrow range and considerable care is necessary to determine the point at which best commutation is obtained. Once determined, however, the brushes need not be moved as the effect of the interpole windings holds the neutral point of the field in the same position for

all load conditions. The neutral point or point of best commutation on non-interpole generators, however, is sensitive to load changes. As the load increases the brushes should be shifted in the direction of rotation to secure best results. If the load on the generating equipment does not vary greatly, the brush position, once determined, need not be changed. With wide changes in load, however, shifting of brushes may be necessary to obtain good commutation under all load conditions.

All electrical connections on the generating equipment should be kept clean and firm. This precaution includes the brush shunts — the flexible cables by means of which the brushes are connected to the electrical circuit. Shunt cables should be securely attached to the brushes and the terminals firmly secured to the brush holders or their mounting at the points provided for this purpose. Loose electrical connections are a frequent source of trouble on electrical equipment but one that is easily avoided by a moderate degree of attention.

Winding faults may be a source of serious commutation difficulties. Open or short circuited field or armature coils, high resistance coil connections, grounded circuits and reversed field windings are some of the winding faults that should be sought when difficulties are encountered on generating equipment. Reversed connections on interpole windings are especially harmful since good commutation cannot be obtained while this condition exists. Open or short circuited coils can usually be located by voltmeter test. Tests of voltage drop at connections with a milli-voltmeter should disclose any high resistance connections. Grounded circuits can be located by the customary ringing test. Polarity of fields can be checked by means of a compass. Interpoles on generators should have the same polarity as the main pole following.

The grade of brush in use exerts a marked influence

on the results obtained. On commutators that are not undercut, that is, those on which the mica is flush with the copper, it is generally desirable to use a brush having a mild abrasive action to keep the mica worn down even with the metallic surface. If the mica is allowed to project above the surface, the brushes will not make firm contact with the copper and the resultant sparking will quickly develop burned bars and flat spots, necessitating regrinding of the commutator. On undercut commutators, which are the general rule today, nonabrasive electro-graphitic brushes give excellent results on most generating equipment used in the projection booth. This type of brush has low friction and excellent commutating characteristics and is hard enough to maintain a good commutator polish under most operating conditions. Sometimes a slight spotting or streaking of the commutator occurs when the arc is struck which the nonabrasive electro-graphitic brush cannot entirely remove before striking the arc again. This condition can be remedied by polishing the commutator surface occasionally with smooth sandpaper. However, to avoid the need for this attention, some operators prefer to use a brush with a slight polishing action, enough to remove this incipient burning but not sufficient abrasive to cause appreciable commutator wear. Graphite or graphite-carbon grades are usually preferred for this purpose. The use of artificially lubricated brushes or the application of lubricant to the commutator surface is not recommended when the mica is undercut and is unnecessary when the proper grade of brush is used.

The grade of brush supplied by the manufacturer of the equipment will generally give satisfactory performance since careful attention is given to brush selection by designing engineers. Distributors of National Projector Carbons also carry in stock National Pyramid Brushes in suitable grades and sizes for all popular makes of motion picture theatre, cur-

rent converting equipment. Replacement brushes of correct grade can thus be obtained without delay from the same source as other theatre supplies. There are cases, however, where operating conditions or other causes indicate the need for a brush of special characteristics. In such cases an outline of your difficulties, mailed to the nearest District Office of Canadian National Carbon Company, Limited, or a discussion of the trouble with a representative of the Company will secure the recommendation of a grade to meet the requirements of your specific case.

Identification of

National Pyramid Brushes

National Pyramid Brushes may be readily distinguished by our registered trade-marks:

The Three Pyramids
and
Silver Strand Cable

Grade number is plainly stamped on each brush where size permits.

Packing and Identification of National Projector Carbons

All National Projector Carbons are packed in strong and convenient corrugated fiber cartons as here illustrated. The size and type of carbon contained in each package is clearly indicated on the end of the carton. Each individual carbon is distinctly marked to show the grade, as indicated on the following page.

Identification of National Projector Carbons

Each individual carbon is stamped with an identifying trade-mark, as shown in the above illustration.

MILLIMETER — INCH EQUIVALENTS

Mm	*Inches*			*Mm*	*Inches*			*Mm*	*Inches*		
1	0.0394	1/32	+	51	2.0079	2.0	+	101	3.9764	3 31/32	+
2	0.0787	5/64	−	52	2.0473	2 1/32	−	102	4.0158	4 1/32	−
3	0.1181	1/8	−	53	2.0866	2 3/64	−	103	4.0551	4 1/16	−
4	0.1575	5/32	+	54	2.1260	2 1/8	+	104	4.0945	4 3/32	+
5	0.1969	13/64	+	55	2.1654	2 5/32	+	105	4.1339	4 1/8	+
6	0.2362	1/4	−	56	2.2047	2 3/32	−	106	4.1732	4 5/32	−
7	0.2756	9/32	−	57	2.2441	2 1/4	−	107	4.2126	4 11/64	−
8	0.3150	5/16	+	58	2.2835	2 9/32	+	108	4.2520	4 1/4	+
9	0.3543	11/32	+	59	2.3228	2 5/16	+	109	4.2914	4 13/64	+
10	0.3937	13/32	−	60	2.3622	2 3/8	−	110	4.3307	4 11/32	−
11	0.4331	7/16	−	61	2.4016	2 13/32	−	111	4.3701	4 3/8	−
12	0.4724	15/32	+	62	2.4410	2 7/16	+	112	4.4095	4 13/32	+
13	0.5118	1/2	+	63	2.4803	2 15/32	+	113	4.4488	4 7/16	+
14	0.5512	9/16	−	64	2.5197	2 1/2	−	114	4.4882	4 1/2	−
15	0.5906	19/32	−	65	2.5591	2 9/16	−	115	4.5276	4 17/32	−
16	0.6299	5/8	+	66	2.5984	2 17/32	+	116	4.5670	4 9/16	+
17	0.6693	21/32	+	67	2.6378	2 5/8	+	117	4.6063	4 19/32	+
18	0.7087	23/32	−	68	2.6772	2 11/16	−	118	4.6457	4 5/8	−
19	0.7480	3/4	−	69	2.7165	2 23/32	−	119	4.6851	4 11/16	−
20	0.7874	25/32	+	70	2.7559	2 3/4	+	120	4.7244	4 23/32	+
21	0.8268	13/16	+	71	2.7953	2 25/32	+	121	4.7638	4 3/4	+
22	0.8661	7/8	−	72	2.8347	2 13/16	−	122	4.8032	4 25/32	−
23	0.9055	29/32	−	73	2.8740	2 7/8	−	123	4.8425	4 13/16	−
24	0.9449	15/16	+	74	2.9134	2 29/32	+	124	4.8819	4 7/8	+
25	0.9843	31/32	+	75	2.9528	2 15/16	+	125	4.9213	4 29/32	+
26	1.0236	1 1/32	−	76	2.9921	3.0	−	126	4.9607	4 31/32	−
27	1.0630	1 1/16	+	77	3.0315	3 1/32	+	127	5.0000	5.0	
28	1.1024	1 3/32	+	78	3.0709	3 1/16	+	128	5.0394	5 1/32	+
29	1.1417	1 5/32	−	79	3.1103	3 3/32	−	129	5.0788	5 1/16	−
30	1.1811	1 3/16	−	80	3.1496	3 1/8	−	130	5.1181	5 3/32	−
31	1.2205	1 7/32	+	81	3.1890	3 5/32	+	131	5.1575	5 5/32	+
32	1.2598	1 1/4	+	82	3.2284	3 3/16	+	132	5.1969	5 3/16	+
33	1.2992	1 9/32	−	83	3.2677	3 7/32	−	133	5.2362	5 1/4	−
34	1.3386	1 11/32	−	84	3.3071	3 5/16	−	134	5.2756	5 9/32	−
35	1.3780	1 3/8	+	85	3.3465	3 11/32	+	135	5.3150	5 5/16	+
36	1.4173	1 13/32	+	86	3.3858	3 3/8	+	136	5.3544	5 11/32	+
37	1.4567	1 15/32	−	87	3.4252	3 7/16	−	137	5.3937	5 3/8	−
38	1.4961	1 1/2	−	88	3.4646	3 15/32	−	138	5.4331	5 7/16	−
39	1.5354	1 17/32	+	89	3.5040	3 1/2	+	139	5.4725	5 15/32	+
40	1.5748	1 9/16	+	90	3.5433	3 17/32	+	140	5.5118	5 1/2	+
41	1.6142	1 5/8	−	91	3.5827	3 9/16	−	141	5.5512	5 17/32	−
42	1.6536	1 21/32	−	92	3.6221	3 5/8	−	142	5.5906	5 9/16	−
43	1.6929	1 11/16	+	93	3.6614	3 11/16	+	143	5.6299	5 5/8	+
44	1.7323	1 23/32	+	94	3.7008	3 23/32	+	144	5.6693	5 21/32	+
45	1.7717	1 3/4	−	95	3.7402	3 3/4	−	145	5.7087	5 11/16	−
46	1.8110	1 13/16	−	96	3.7795	3 25/32	−	146	5.7481	5 3/4	−
47	1.8504	1 27/32	+	97	3.8189	3 13/16	+	147	5.7874	5 23/32	−
48	1.8898	1 7/8	+	98	3.8583	3 27/32	+	148	5.8268	5 13/16	+
49	1.9291	1 15/16	−	99	3.8977	3 7/8	−	149	5.8662	5 7/8	+
50	1.9685	1 31/32	−	100	3.9370	3 15/16	−	150	5.9055	5 15/16	−

NOTE — The + or − sign indicates that the decimal equivalent is larger or smaller than the fractional equivalent.

MILLIMETER — INCH EQUIVALENTS

Mm	*Inches*			*Mm*	*Inches*			*Mm*	*Inches*		
151	5.9449	$5\frac{15}{64}$	+	201	7.9134	$7\frac{23}{32}$	+	251	9.8819	$9\frac{7}{8}$	+
152	5.9843	$5\frac{31}{32}$	+	202	7.9528	$7\frac{15}{16}$	+	252	9.9213	$9\frac{29}{32}$	+
153	6.0237	$6\frac{1}{32}$	−	203	7.9922	8.0	−	253	9.9607	$9\frac{31}{32}$	−
154	6.0630	$6\frac{1}{16}$	+	204	8.0315	$8\frac{1}{32}$	+	254	10.0000	10.0	
155	6.1024	$6\frac{3}{32}$	+	205	8.0709	$8\frac{1}{16}$	+	255	10.0394	$10\frac{1}{32}$	+
156	6.1418	$6\frac{5}{32}$	−	206	8.1103	$8\frac{1}{16}$	−	256	10.0788	$10\frac{3}{32}$	−
157	6.1811	$6\frac{3}{16}$	−	207	8.1496	$8\frac{5}{32}$	−	257	10.1182	$10\frac{1}{16}$	−
158	6.2205	$6\frac{7}{32}$	+	208	8.1890	$8\frac{3}{16}$	+	258	10.1575	$10\frac{5}{32}$	+
159	6.2599	$6\frac{1}{4}$	+	209	8.2284	$8\frac{7}{32}$	+	259	10.1969	$10\frac{3}{16}$	+
160	6.2993	$6\frac{9}{16}$	−	210	8.2678	$8\frac{9}{32}$	−	260	10.2363	$10\frac{1}{4}$	−
161	6.3386	$6\frac{11}{32}$	−	211	8.3071	$8\frac{5}{16}$	−	261	10.2756	$10\frac{9}{32}$	−
162	6.3780	$6\frac{5}{16}$	+	212	8.3465	$8\frac{11}{32}$	+	262	10.3150	$10\frac{5}{16}$	+
163	6.4174	$6\frac{13}{32}$	+	213	8.3859	$8\frac{3}{8}$	+	263	10.3544	$10\frac{11}{32}$	+
164	6.4567	$6\frac{15}{32}$	−	214	8.4251	$8\frac{7}{16}$	−	264	10.3938	$10\frac{13}{32}$	−
165	6.4961	$6\frac{1}{2}$	−	215	8.4646	$8\frac{15}{32}$	−	265	10.4331	$10\frac{7}{16}$	−
166	6.5355	$6\frac{17}{32}$	+	216	8.5040	$8\frac{1}{2}$	+	266	10.4725	$10\frac{15}{32}$	+
167	6.5748	$6\frac{9}{16}$	+	217	8.5433	$8\frac{17}{32}$	+	267	10.5119	$10\frac{1}{2}$	+
168	6.6142	$6\frac{5}{8}$	−	218	8.5827	$9\frac{9}{32}$	−	268	10.5512	$10\frac{9}{16}$	−
169	6.6536	$6\frac{21}{32}$	−	219	8.6221	$8\frac{5}{8}$	−	269	10.5906	$10\frac{17}{32}$	−
170	6.6929	$6\frac{11}{16}$	+	220	8.6615	$8\frac{21}{32}$	+	270	10.6300	$10\frac{5}{8}$	+
171	6.7323	$6\frac{23}{32}$	+	221	8.7008	$8\frac{11}{16}$	+	271	10.6693	$10\frac{21}{32}$	+
172	6.7717	$6\frac{25}{32}$	−	222	8.7402	$8\frac{3}{4}$	−	272	10.7087	$10\frac{11}{16}$	−
173	6.8111	$6\frac{13}{16}$	−	223	8.7796	$8\frac{23}{32}$	−	273	10.7481	$10\frac{3}{4}$	−
174	6.8504	$6\frac{27}{32}$	+	224	8.8189	$8\frac{13}{16}$	+	274	10.7875	$10\frac{23}{32}$	+
175	6.8898	$6\frac{7}{8}$	+	225	8.8583	$8\frac{27}{32}$	+	275	10.8268	$10\frac{13}{16}$	+
176	6.9292	$6\frac{15}{32}$	−	226	8.8977	$8\frac{29}{32}$	−	276	10.8662	$10\frac{7}{8}$	−
177	6.9685	$6\frac{31}{32}$	−	227	8.9371	$8\frac{15}{16}$	−	277	10.9056	$10\frac{29}{32}$	−
178	7.0079	7.0	+	228	8.9764	$8\frac{31}{32}$	+	278	10.9449	$10\frac{15}{16}$	+
179	7.0473	$7\frac{1}{16}$	−	229	9.0158	$9\frac{1}{32}$	−	279	10.9843	$10\frac{31}{32}$	+
180	7.0866	$7\frac{3}{32}$	−	230	9.0552	$9\frac{1}{16}$	−	280	11.0237	$11\frac{1}{32}$	−
181	7.1260	$7\frac{1}{16}$	+	231	9.0945	$9\frac{3}{32}$	+	281	11.0630	$11\frac{1}{16}$	+
182	7.1654	$7\frac{5}{32}$	+	232	9.1339	$9\frac{1}{8}$	+	282	11.1024	$11\frac{3}{32}$	+
183	7.2048	$7\frac{7}{32}$	−	233	9.1733	$9\frac{5}{32}$	−	283	11.1418	$11\frac{1}{8}$	−
184	7.2442	$7\frac{1}{4}$	−	234	9.2126	$9\frac{3}{16}$	−	284	11.1812	$11\frac{5}{32}$	−
185	7.2835	$7\frac{9}{32}$	+	235	9.2520	$9\frac{1}{4}$	+	285	11.2205	$11\frac{3}{16}$	+
186	7.3229	$7\frac{5}{16}$	+	236	9.2914	$9\frac{9}{32}$	+	286	11.2599	$11\frac{1}{4}$	+
187	7.3622	$7\frac{23}{32}$	−	237	9.3308	$9\frac{11}{32}$	−	287	11.2993	$11\frac{9}{32}$	−
188	7.4016	$7\frac{13}{32}$	−	238	9.3701	$9\frac{3}{8}$	−	288	11.3386	$11\frac{5}{16}$	−
189	7.4410	$7\frac{7}{16}$	+	239	9.4095	$9\frac{13}{32}$	+	289	11.3780	$11\frac{11}{32}$	+
190	7.4804	$7\frac{15}{32}$	+	240	9.4489	$9\frac{7}{16}$	+	290	11.4174	$11\frac{13}{32}$	+
191	7.5197	$7\frac{17}{32}$	−	241	9.4882	$9\frac{15}{32}$	−	291	11.4567	$11\frac{15}{32}$	−
192	7.5591	$7\frac{9}{16}$	−	242	9.5276	$9\frac{1}{2}$	−	292	11.4961	$11\frac{1}{2}$	−
193	7.5985	$7\frac{19}{32}$	+	243	9.5670	$9\frac{9}{16}$	+	293	11.5355	$11\frac{17}{32}$	+
194	7.6378	$7\frac{5}{8}$	+	244	9.6063	$9\frac{17}{32}$	+	294	11.5749	$11\frac{9}{16}$	+
195	7.6772	$7\frac{11}{16}$	−	245	9.6457	$9\frac{11}{16}$	−	295	11.6142	$11\frac{5}{8}$	−
196	7.7166	$7\frac{23}{32}$	−	246	9.6851	$9\frac{19}{32}$	−	296	11.6536	$11\frac{21}{32}$	−
197	7.7559	$7\frac{25}{32}$	+	247	9.7245	$9\frac{23}{32}$	+	297	11.6930	$11\frac{11}{16}$	+
198	7.7953	$7\frac{13}{16}$	+	248	9.7638	$9\frac{3}{4}$	+	298	11.7323	$11\frac{23}{32}$	+
199	7.8347	$7\frac{27}{32}$	−	249	9.8032	$9\frac{13}{16}$	−	299	11.7717	$11\frac{25}{32}$	−
200	7.8741	$7\frac{7}{8}$	−	250	9.8426	$9\frac{27}{32}$	−	300	11.8111	$11\frac{13}{16}$	−

NOTE — The + or − sign indicates that the decimal equivalent is larger or smaller than the fractional equivalent.

Decimal Equivalents of Fractions and Equivalents of Fractions of an Inch in M. M.

Fractions	Decim. of an inch	mm.	Fractions	Decim. of an inch	mm.
1/64	.015625	.397	33/64	.515625	13.097
1/32	.031250	.794	17/32	.531250	13.494
3/64	.046875	1.191	35/64	.546875	13.891
1/16	.062500	1.588	9/16	.562500	14.288
5/64	.078125	1.984	37/64	.578125	14.684
3/32	.093750	2.381	19/32	.593750	15.081
7/64	.109375	2.778	39/64	.609375	15.478
1/8	.125000	3.175	5/8	625000	15.875
9/64	.140625	3.572	41/64	.640625	16.272
5/32	.156250	3.969	21/32	.656250	16.669
11/64	.171875	4.366	43/64	.671875	17.066
3/16	.187500	4.763	11/16	.687500	17.463
13/64	.203125	5.159	45/64	.703125	17.859
7/32	.218750	5.556	23/32	.718750	18.256
15/64	.234375	5.953	47/64	.734375	18.653
1/4	.250000	6.350	3/4	.750000	19.050
17/64	.265625	6.747	49/64	.765625	19.447
9/32	.281250	7.144	25/32	.781250	19.844
19/64	.296875	7.541	51/64	.796875	20.241
5/16	.312500	7.938	13/16	.812500	20.638
21/64	.328125	8.334	53/64	.828125	21.034
11/32	.343750	8.731	27/32	.843750	21.431
23/64	.359375	9.128	55/64	.859375	21.828
3/8	.375000	9.525	7/8	.875000	22.225
25/64	.390625	9.922	57/64	.890625	22.622
13/32	.406250	10.319	29/32	.906250	23.019
27/64	.421875	10.716	59/64	.921875	23.416
7/16	.437500	11.113	15/16	.937500	23.813
29/64	.453125	11.509	61/64	.953125	24.209
15/32	.468750	11.906	31/32	.968750	24.606
31/64	.484375	12.303	63/64	.984375	25.003
1/2	.500000	12.700	1	1.0000000	25.400

PHOTOMETRIC UNITS

Luminous Intensity (Candlepower) — Unit: Candle

The standard candle is maintained by the national laboratories of France, Great Britain and the United States.

Luminous Flux — Unit: Lumen

One lumen is the flux emitted within a solid angle of one steradian from a point source of unit candle power. A source of unit spherical candle power emits 12.57 lumens.

Illumination Units:

Lux	=1 lumen incident per square meter =0.0001 phot =0.0929 foot-candle
Phot	=1 lumen incident per sq. cm. =10,000 lux =929 foot-candles
Foot-candles	=1 lumen incident per sq. ft. =10.76 lux =0.001076 phot

Brightness Units:

Candle per sq. cm.	=3.1416 lamberts =2919 foot-lamberts
Candle per sq. in.	=0.487 lambert =452 foot-lamberts
Lambert	=1 lumen emitted per sq. cm. =0.3183 candle per sq. cm. =2.054 candles per sq. in. =929 foot-lamberts
Foot-lambert	=1 lumen emitted per sq. ft. =0.001076 lambert =0.000343 candle per sq. cm. =0.00221 candle per sq. in.

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